The Electric journal

Electric Club, Westinghouse Club

THE

ELECTRIC JOURNAL

VOL. VI

JANUARY-DECEMBER

1909

Published by

THE ELECTRIC CLUB

PITTSBURG, PA.

THE ELECTRIC JOURNAL

THE ELECTRIC JOURNAL is published by The Electric Club. The Journal is unique in having the support of an active electrical society which numbers among its members the engineers of a large electric company, as the Club is composed principally of men connected with the Westinghouse Electric & Manufacturing Company.

The aim of the Journal is to be direct, definite and practical, and to be recognized by progressive electrical men as one of the indispensable aids to effective engineering work.

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ELECTRIC JOURNAL

**Five
Years
of the
Journal**
Since its very modest beginning in February, 1904, the JOURNAL has continued until there are now completed five volumes, in publishing which considerably over one hundred tons of paper have been used. Several hundred men, many of them experienced practicing engineers, who write but little for publication, have contributed 3500 pages of reading matter, a considerable proportion of which is of as much interest and value now as when first issued.

In the initial issue of the JOURNAL five years ago, the purpose of The Electric Club Journal was set forth as a feature of The Electric Club, whose prime object was to increase the opportunities available to the young men on the engineering apprenticeship course of the Westinghouse Electric & Manufacturing Company. In this course are more post-graduate electrical students than in all the universities and technical schools of the country combined. The manufacturing company with its great works filled with apparatus of all types in every stage or construction, with its testing departments, its skilled workmen, its active engineers, its marvelous organization by which thousands of men act together to accomplish a common end, gives to the young engineering apprentice opportunity for acquiring knowledge and experience up to the limit fixed by his ability and activity. Supplementing the factory experience is The Electric Club with lectures and discussions, formal and informal, and the entermingling of men from scores of schools and many countries. To supplement all this came this JOURNAL to put in permanent form the kind of technical and engineering and other material most useful to the young man fitting himself for an electrical engineering career. In this way the unique advantages of the apprenticeship course and The Electric Club were extended to engineers everywhere.

The initial purpose, therefore, was to make this JOURNAL a definite and positive factor in the education and development of young engineers. Since the JOURNAL was established, some 1 200 or 1 500 young men have passed through the apprenticeship course,

most of whom are now in active work in various fields. It is evident, however, from the large size of the JOURNAL subscription list, that only a very small percentage of the number of JOURNALS printed go to apprentices. It has been found that articles dealing in a concrete definite manner with the principles, manufacture and performance of modern apparatus and discussing engineering problems and practice in a simple direct way, by men who are practical workers rather than professional writers, have appealed alike to the technical student, the consulting, the erecting and operating engineer, and to the business man and even to the physician who is interested in fields other than his own. In a number of colleges, certain of its articles have a definite part in the instruction schedules.

One difficulty in the convenient use of back volumes of ordinary engineering publications and the transactions of societies is the lack of an efficient, up-to-date, general index. For several years the JOURNAL has issued a complete index each year to all preceding volumes. A single classified topical index now covers the first five columns, giving them a cyclopaedic value. This method of indexing has increased the demand for early volumes and thousands of dollars have been expended in reprinting back issues of which the supply had become exhausted. The bound volume business has exceeded five thousand copies—a good indication of the importance attached to the permanent value of the material which has been published, much of which is not elsewhere accessible.

It was the ambition of those who fostered the JOURNAL in its early days to make it an effective instrument in the progress of electrical engineering development. It was hoped that this might be accomplished by a periodical by the young engineer and for the young engineer, which made engineering merit and usefulness to its readers its editorial criterion. Our ideals have grown from year to year and while we have never overtaken them, yet it will scarcely be denied that the JOURNAL has developed a new field, almost a new type, of journalism—one which is now accepted as an established and effective factor not only in extending definite electrical engineering knowledge, but in advancing that point of view and those elements of professional and moral character which are the real basis of individual success and of electrical progress.

The success which the JOURNAL has met has been due in a large measure to the support and interest taken by its good friends, principally its subscribers and its contributors. The latter have done their important part through their interest in the JOURNAL without

compensation other than the rewards of a happy conscience and the distinction of being numbered in the list of contributors.

During the past year there has been an active reciprocal relationship between editor and reader through THE JOURNAL QUESTION BOX. Questions from most of the states and foreign countries have been received and answered in such a way that actual perplexities and their solutions by expert engineers have gone forth to thousands of readers.

A change in the JOURNAL is noted in reviewing the back volumes. Many of the early articles dealt with concrete factory practice, in construction, winding and testing. This field has been fairly well covered and later tables of contents show more engineering essays or papers of the character appropriate for an engineering society. A large proportion of the elementary practical material has found place in the QUESTION BOX. Editorial problems of selection of subjects and manner of treatment naturally change as volumes increase in number. The co-operation of readers and contributors is invited to aid in making the result most effective.

As sentiment in the carrying out of a unique idea has been an underlying factor in the development of this JOURNAL, we have assumed a similar interest on the part of many of our readers, as a justification for this extended editorial shop talk. They may be further interested in knowing that while we have naturally felt the effect of the recent panic, we have rounded out the year with a healthy increase in business over that of the preceding year.

For 1909 we repeat the foreword of a year ago:—"To be of use to our readers; to be of real assistance to electrical engineers, present and future, and to be an active force in accelerating the progress and advancing the best interests of the electrical engineering profssion—those are the aims and ambitions with which we enter the New Year."

THE PUBLICATION COMMITTEE

The Single-Phase Railway Motor In "The Log of the New Haven Electrification" presented before the American Institute of Electrical Engineers at its December meeting, it is significant to note how little attention is paid to the motor in an account of the operation of this single-phase system. In the list of causes of delay the motor is scarcely mentioned. In fact, it seems to be a feature of the system which attracts minimum attention and comment, as its record in service leaves no doubt as to its reliability.

Many will recall the interest which centered in the single-phase motor several years ago when Mr. Lamme first described before the Institute in the Fall of 1902 a proposed single-phase system. Little attention was paid to any of the elements aside from the motor. Great curiosity was aroused as to what mysterious feature had been introduced into a type of machine, which everybody recognized as impracticable, in order to transform it into a useful motor capable of doing efficient service without distress at its commutator. The consensus of opinion, as expressed by engineers and the technical press generally, was to the effect that if a single-phase railway motor could successfully commutate its current, a revolution was likely to take place in railway operation.

In this issue is printed an article by Mr. Lamme giving in a simple way the characteristics of the single-phase commutator type motor, which explains various features in its design and operation. The article is happily expressed in ordinary terms without the use of the mathematical auxiliaries which are often used to embellish dissertations upon alternating-current motors. The article will, therefore, appeal to the general reader and will go far to explain how it is that such motors may operate for many months and for many thousands of miles without an appreciable effect upon their commutators or brushes.

The Westinghouse Companies

In the December issue of the JOURNAL a year ago there appeared a very appreciative tribute to Mr. George Westinghouse, taken from the *Railroad Gazette*. At that time, to the ordinary observer, it would have seemed that he was overwhelmed by misfortune. All but two of his large American Companies were in the hands of receivers and his personal fortune was so involved that many people did not believe it possible that he could retrieve himself. This was on the assumption that he was an average man. Of such a man this prognostication would undoubtedly have been true. An average man would have been completely crushed and could never have rehabilitated himself and his Companies. Obviously, however, a man whose fame has become world wide is not an average man, but an extraordinary one and those who knew him best were confident that Mr. Westinghouse would pull the Companies through and get them back on their feet in as good condition as ever.

It is exceedingly gratifying to make the record a year after the one of disaster just the reverse and one that is full of hope and

bright prospects. Referring particularly to the Electric Company in whose work the readers of the JOURNAL are particularly interested, its financial embarrassments have been removed and in such a far-sighted and masterly way that the best financial authorities assert it is now in better financial condition than at any time in its past history. The organization has been preserved practically intact, as scarcely a man in an important position became so discouraged as to leave the Company's service. Those who were in position to know were well aware of this fine spirit of loyalty to the Company and to Mr. Westinghouse, but the past year gave an opportunity to show how this loyalty would stand the test of severe trial, which it did splendidly.

It is particularly worthy of note that the employees submitted to a reduction of salary during the receivership without murmur, although it involved serious hardship to a great many. As they felt that the embarrassment was only temporary and that, as soon as the financial matters would be adjusted, the prosperity of the Company would return with that of the country at large, they went ahead without loss of energy or zeal. ,

A further evidence of the spirit which pervades the employees as a body was shown when the effort was made to get existing stockholders to subscribe for an increase of stock in order to increase the working capital of the Company. Owing to the absolute inability of some stockholders to do this, a committee of the employees, of their own motion, started voluntary subscriptions among the employees and secured in all the sum of about $600 000 from over 5 000 persons. Many of these subscriptions were for small amounts, often for a single share from employees with small salaries, but everyone was anxious to do his part. It is understood that the spirit displayed by the employees had great weight with the Readjustment Committee in convincing them of the value of the Company as a going concern.

From time to time during the year comments on the prospects of the Company appeared in the technical journals and daily press. In these articles it was pointed out that the Electric Company occupies a position far more important than a mere manufacturer of electric machinery, and that its splendid record as a leader in the development of the electric industry and its great importance in the further development of the applications of electricity make it a national institution to which any serious misfortune would mean a severe blow to the prestige of the country.

Meter Development

Three forms of tests are almost invariably necessary in the ultimate successful development of practical electrical apparatus:—Research or investigative tests, upon which the the design is to be based; performance tests, the purpose of which is to prove the correctness of the design, and service tests, which determine the practical utility of the apparatus. While examples may be cited of apparatus possessing in its original design practically all of the essential qualities and characteristics, yet the more usual process of development is one of evolution, and in this the service test bears a most important part. The foresight required of the designing engineer in the anticipation of practical difficulties which must be surmounted in the inherent design of the apparatus is acquired only through experience in both the operation and manufacture of the apparatus. Operation under service conditions serves to indicate wherein the practical utility of the machine may be improved, and its manufacture on a commercial scale serves to indicate wherein economies may be affected through modifications in design. ·

With this in mind, the importance and interest of the notes by Mr. Paul MacGahan in this issue of the JOURNAL, on the "Disc Type Induction Ammeters and Voltmeters" will be appreciated.

The rapid developments of the last fifteen years in the direction of electric meter engineering are apt to be overlooked because, to-day, electric power is in universal use and measured by means of simple, accurate, yet comparatively inexpensive indicating and registering devices. It is interesting to consider the meter situation of approximately ten years ago, for example, as regards Westinghouse meters. At that time the principal line of indicating meters was the magnetic vane, gravity controlled type. These were used for alternating and direct-current measurements. Weston instruments were also used on many direct current switchboards. The horizontal edgewise Shallenberger induction type was also occasionally used, especially for large switchboards where wattmeters were also installed. Integrating meters were represented by the Shallenberger alternating-current ampere-hour meter and the Shallenberger induction wattmeter. The so-called "glass and marble" type of solenoid instrument and the Waterhouse indicating meters were obsolete. There were no graphic meters, or portable types. The static ground detector, the induction type frequency meter, synchroscopes power-factor·meters, single air-gap type direct-current instruments, etc., have all been developed during the last decade.

THE SINGLE-PHASE COMMUTATOR-TYPE MOTOR*

B. G. LAMME

THE broad statement may be made that it is no more difficult to commutate an alternating current than an equal direct current. Such a statement would appear to be entirely contrary to the usual experience, but a little study of the matter will show where the apparent discrepancy lies. In commutator type alternating-current motors, as usually built, a relatively large number of commutator bars passes under the brush during one alternation of the supply current. While the current supplied is varying from zero to maximum value and back to zero, possibly 50 bars have been passed under the brush, and therefore 50 coils in the armature have been reversed or commutated. Some of these reversals occur at the top of the current wave which has a value of about 40 percent higher than the mean or effective value which is read by the ammeter. The motor is therefore at times commutating 40 percent higher current than that indicated by the instruments. It is thus evident that in comparing the commutation of 100 amperes direct current with 100 amperes alternating current we should actually compare the direct current with 141 amperes alternating. In other words, for commutating equal currents alternating current or direct current, the alternating-current ammeter should register only 71 percent as much current as the direct current. Another way of expressing it is that we have to commutate the top or maximum of the alternating-current wave, while our instruments only record the mean value.

If the above represented the only difference between the alternating current and direct current the problem to be solved in commutation of alternating current would not be serious. However, the current to be commutated by an alternating-current motor is not merely the working current supplied to the motor and measured by the ammeter, but there is, in addition, a current which is generated in the motor itself, both at standstill and during rotation, which has to be reversed or commutated along with the working current. It is this latter current, usually called the local or short-circuit current, which has been the source of greatest trouble in commutating alternating current; for this short-circuit current may

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*From a paper presented at the Philadelphia Section of the American Institute of Electrical Engineers. Revised by the author.

have a value anywhere from three to ten times the working current, depending on the design of the machine. Therefore in comparing the commutation of an alternating current, as indicated by an ammeter with an equal direct current, we should, in reality, consider that the alternating-current motor is commutating a maximum current from five to ten times the value of the indicated current. Furthermore, it would not do to reduce the ammeter current to one-fifth or one-tenth value in order to compare commutation with direct current, because by so doing we would simply be reducing the small applied component of the total current commutated by the brushes, the local or short-circuit current still retaining a rather high value. In order to compare with direct-current commutation, it would be necessary for the total maximum of the combined supply and the short-circuit current to be reduced to the same value as direct current.
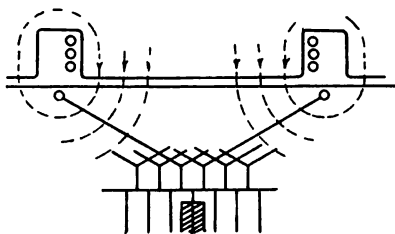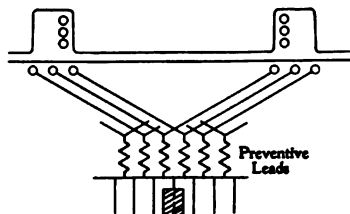
FIG. 1   FIG. 2

Hence, the local current in the armature turn short-circuited by the brush is the source of practically all the trouble in commutating alternating currents. Fig. 1 illustrates a portion of the field and armature structure of a commutator type alternating-current motor. It will be noted that the armature conductor which is in the neutral position between poles, surrounds the magnetic flux from the field pole, just as the field turns themselves surround it. The field flux being alternating, this armature turn will have set up in it an electromotive force of the same value as one of the field turns. Short-circuiting the two ends of this armature turn should have the same effect as short-circuiting one of the field turns, which is the same thing as short-circuiting a turn on a transformer. Such a short-circuited turn, if of sufficiently low resistance, should have as many ampere-turns set up in it as there are field ampere turns. In single-phase motors of good design the field ampere-turns per pole are about twelve to fifteen times the normal ampere-turns in any one armature coil. Therefore, if the

armature coil in the position shown in Fig. 1 should have its ends closed on themselves the current in this coil would rise to a value of twelve to fifteen times normal. In reality, it would not rise quite this much, because this armature turn is placed on a separate core from the field or magnetizing turns with an air-gap between, so that the magnetic leakage between the primary (or field winding) and this secondary (or armature winding) would tend to protect this coil somewhat, just as leakage between the primary and secondary windings of a transformer tends to reduce the secondary electromotive force and current. Also, this armature coil is embedded in slots, thus adding somewhat to its self-induction, and tending further to reduce the short-circuit current. In consequence, with its ends closed together the current in this armature coil would probably not rise more than ten to twelve times above normal value under any condition. It is evident, therefore, that if the brush, shown in Fig. 1 as bridging across two commutator bars to which the ends of this coil are connected is of copper or other low-resistance material, then there could be an enormous local current set up in the coil when thus short-circuited by the brush. This local current of about ten times the normal working current would have to be commutated as the brush moves from bar to bar, and therefore the operation of the machine would be similar to that of a direct-current motor if overloaded about ten times in current. In other words, there would be vicious sparking.

Even if the low-resistance brush were replaced by one of ordinary carbon, the short-circuiting current would still be relatively high, due to the fact that it is not allowable to make the brush contact of very high resistance by reducing the size or number of the brushes, because these same brushes must carry the working current supplied to the motor, and there must be brush capacity sufficient to handle this current. This brush capacity will, in practice, be of such amount that the resistance in bridging from one bar to the next is still rather low, although much higher than if a copper brush were used. Experience shows that with not more than four or five volts generated in this short-circuited coil by the field flux, the resistance of the carbons at the contact with the commutator would be such that a short-circuit current of three to four times the normal working current in the coil can still flow. Therefore, if the motor were equipped with carbon brushes and had but four or five volts generated in the short-circuit coil, the motor would have to commutate the main or working current and also a short-circuit

current of possibly three times the amount.   This short-circuit current would also have a maximum or top of its current wave. Assuming 100 amperes as the current supplied to the motor, the machine therefore actually commutates a supply current of 141 amperes and an additional short-circuit current of possibly three times this value, or from 400 to 500 amperes; therefore, the motor actually commutates the equivalent of about 600 amperes direct current when the alternating current ammeter is reading 100.   It is evident from this that any one who tries to commutate alternating current with an ordinary type of commutating machine would at once draw the conclusion that alternating current in itself is very difficult to commutate, naturally overlooking the fact that it is the excessive current handled by the brush that is back of the trouble, and not the current indicated by the ammeter.   .

All efforts of designers of alternating-current commutator motors have been in the direction of reducing or eliminating this local current.   The present success of the motor, in the various forms brought out, is largely due to the fact that this current has been successfully reduced to so low a value that it does not materially add to the difficulties of commutating the main current.   No successful method has yet been practically developed for entirely overcoming the effects of this short-circuit current under all conditions from standstill to highest speed.   Some of the corrective methods developed almost eliminate this current at a certain speed or speeds, but have little or no corrective effect under other conditions; other methods do not effect a complete correction at any speed, but have a relatively good effect at all speeds and under all conditions.   The former methods would appear to be applicable to motors which run at, or near, a certain speed for a large part of the time; the latter method would be more applicable to those cases where the motor is liable to be operated for considerable periods with practically any speed from standstill to the highest.   While several methods have been brought forward for correcting local current when the motor has obtained speed, yet up to the present time but one successful method has been developed for materially reducing this current at standstill or very low speeds. It may be suggested that the short-circuit voltage per coil be reduced to so low a value, say four or five volts, that the local current is not excessive and does not produce undue sparking.   This would certainly reduce the sparking difficulty, but is open to the very great objection that the capacity of the motor is directly affected

by a reduction in the short-circuit voltage. This voltage per turn in the armature coil is a direct function of the value of the alternating field-flux and its frequency. Assuming a given frequency, then the short-circuit voltage is a direct function of the induction per field pole, and the lower the short-circuit voltage the lower must be the field flux. But the output of the machine, or the torque with a given speed, is proportional to the product of the field flux per pole by the armature ampere turns. In a given size of armature the maximum permissible number of ampere turns is dependent upon mechanical and heating considerations, and therefore with a given armature the torque of the motor is a direct function of the field flux. Using the maximum permissible armature ampere-turns, the output of a given motor would be very low if the field flux were so low that the short-circuit voltage would not be more than three or four volts. Increasing the field induction, and therefore increasing the short-circuit voltage, increases the output.

Experience shows that on large motors, such as required for railway work, the induction per pole must necessarily be so high that the electromotive force in the short-circuit coil must be about double the figure just given; therefore, with such heavy flux the short-circuited current will necessarily be excessive unless some corrective means is used for reducing it.

I will consider the standstill or low-speed condition first. For this condition only one practical arrangement has so far been suggested for reducing the local current to a reasonably low value compared with the working current. This method involves the use of preventive leads, or, as they are sometimes called, resistance leads. These consist of resistances connected between the commutator bars and the armature conductors. Fig. 2 illustrates the arrangement. The armature is wound like a direct-current machine, except that the end of one armature coil is connected directly to the beginning of the next without being placed in the commutator. Between these connections separate leads are carried to the commutator bars, and in these leads sufficient resistance is placed to cut down the short-circuit current. The arrangement is very similar in effect to the preventive coils used in connection with step-by-step voltage regulators which have been in use for many years. In passing from one step to the next on such regulators, it is common practice to introduce a preventive coil or resistance in such a way

that the two contact bars are bridged only through this preventive device.

In an armature winding arranged in this way, the working current is introduced through the brushes and the leads to the armature winding proper. After entering the winding, the current does not pass through the resistance leads because the connections between coils are made beyond these leads. In consequence, only a very small number of these leads are in circuit at any one time; when the armature is in motion all the leads carry current in turn so that the average loss in any one lead is very small. As the brush generally bridges across two or more commutator bars, there is usually more than one lead in circuit, but generally not more than three. When the brush is bridging across two bars, there is not only the working current passing into the two leads connected to these two bars, but there is the local current, before described, which passes in through one lead, through an armature turn, then back through the next lead to the brush. There are losses in these two leads due to these two currents. By increasing the resistance, the loss due to the working current is increased, but at the same time the short-circuit current is decreased. As the loss due to this latter is equal to the square of the current multiplied by the resistance, it is evident that increasing this resistance will cut down the loss due to the local current in direct proportion as the resistance is increased. When the working current is much smaller in value than the short-circuit current, an increase in the resistance of the leads does not increase the loss due to the working current as much as it decreases the loss due to the short-circuit current. Both theory and practice show that when the resistance in the leads is so proportioned that the short-circuit current in the coil is equal to the normal working current, the total losses are a minimum. Calculation, as well as experience, indicates that a variation of twenty to thirty percent at either side of this theoretically best resistance gives but a very slight increase in loss, so there is considerable flexibility in the adjustment of this resistance. The resistance of the brush contacts and of the coil itself must be included with the resistance of the leads in determining the best value. In practice it is found that with ordinary medium-resistance brushes, the resistance in the leads themselves should be about four or five times as great as the resistance in the brush contact and the coil; that is, it is usual to calculate the total necessary resistance required and then place about seventy or eighty percent of it in the leads themselves.

When leads of the proper proportion are added to the motor, it is found that practically twice as high field flux can be used as before with the same sparking and burning tendency as when the lower flux is used without such leads. But even with six to eight volts per commutator bar as a limit, a handicap is encountered in the design of the motors, especially when the frequency is taken into account. This limited voltage between bars also indicates at once why single-phase railway motors are wound for such relatively low armature voltages. Direct-current railway motors commonly use from 12 to 20 volts per commutator bar, or from 2 to 2.5 times the usual practice on alternating-current motors. With this low voltage between bars in alternating-current machines, with the largest practicable number of bars, the armature voltages become 200 to 250, or about forty percent of the usual direct-current voltages. The choice of low voltage should, therefore, not be considered as simply a whim of the designers; it is a necessity which they would gladly avoid if possible.

Assuming preventive leads of the best proportions, let us again compare the current to be commutated in an alternating-current motor with that of the direct-current. Considering the ammeter reading as 100, the working alternating current has a maximum value of 140 and in addition there is a short-circuit current of the same value. Even under this best condition, the alternating-current motor must commutate a current several times as large as in the corresponding direct-current motor. The design of such a motor, therefore, is a rather difficult problem, even under the best conditions.

I will now take up the question of power-factor in the single-phase commutator motor. In a direct-current motor we have two electromotive forces which add up equal to the applied electromotive force; namely, the counter electromotive force due to rotation of the armature winding in the magnetic field, and the electromotive force absorbed in the resistance of the windings and rheostat. In the alternating-current motor there are these two electromotive forces, and there is also another one not found in the direct-current machine; namely, the electromotive force of self-induction of the armature and field windings due to the alternating magnetic flux in the motor. This inductive electromotive force exerts a far greater influence than the ohmic electromotive force for it has much higher values.

The inductive electromotive force lies principally in the main

field or exciting winding of the alternating-current motor. There is a certain voltage per turn generated in the field coils, depending upon the amount of the field flux and its frequency, as stated before. This electromotive force per field turn is practically of the same value as the short-circuit electromotive force generated in the armature coil, as already referred to. I have stated that a short-circuit voltage of three or four volts per armature turn gave prohibitive designs and that it was necessary practically to double this. This means that the field coils also have six to eight volts per turn generated in them. The total number of field turns must, therefore, be very small in order to keep down the field electromotive force, for this represents simply a choke coil in series with the armature. If the armature counter electromotive force should be 200 volts, for instance, which is rather high in practice with 25-cycle motors, then a field self-induction of half this value would allow about 14 turns total in the field winding. Compare this with direct-current motors with 150 to 200 field turns for 550 volts, or 60 to 80 turns for 220 volts. The alternating current 25-cycle motor, therefore, can have only about 20 to 25 per cent as many field turns as the ordinary direct-current motor. This fact makes it particularly hard to design large motors where there must be many poles. In the single-phase motor the induction per pole being limited by the permissible short-circuit voltage, it is necessary to use a large number of poles for heavy torques; but the total number of field turns must remain practically constant on account of the self-induction, while in reality the number of turns should be increased as the number of poles is increased. With a given number of poles we may have just sufficient field turns to magnetize the motor up to the required point; but if a large number of poles should be required, then we at once lack field turns and must either reduce the field induction, and thus reduce the output, or must add more field turns and thus get a higher self-induction or choking action in the field, with a consequent reduction in power-factor. Here is where a lower frequency comes in to advantage, for, with the same relative inductive effect, the field turns can be increased directly as the frequency is decreased. The use of 15 cycles permits 67 percent more field turns than 25 cycles and raises our permissible magnetizing limits enormously. This problem is encountered particularly in gearless locomotive motors of large capacity. For increased capacity the driving wheels are made larger, thus permitting a larger diameter

of motor, the length, axlewise, being fixed. Bnt with increased diameter of drivers, the number of revolutions is decreased for a given number of miles per hour. With 25 cycle motors we soon encounter the above mentioned limiting condition in field turns; beyond this point the characteristics of the motor must be sacrificed, and even doing this we soon reach prohibitive limits. By dropping the frequency to 15 cycles, for instance, we change the whole situation. The induction per pole can be increased and the number of poles, if desired, can also be increased. The practical result is that, in the case of a high-speed passenger locomotive with gearless motors, a 700 hp., 15 cycle motor can be put in on the same diameter of drivers as required for a 500 hp., 25 cycle moto1. Also a 500 hp., 15 cycle motor may be put on the same drivers as a 300 hp., 25 cycle motor. At the same time these 15 cycle motors have better all round characteristics than the 25 cycle machines as regards efficiency, power-factor, starting, over-load commutation, etc.
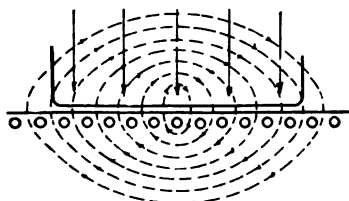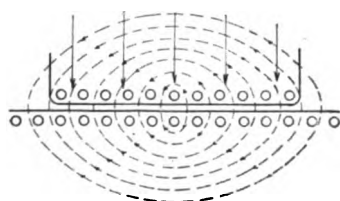
FIG. 3   FIG. 4

Returning to the design of the motor, there is one other electromotive force of self-induction which may be considered; namely, that generated in the armature winding and in the opposing winding in the pole face, usually called the neutralizing or compensating winding.

Fig. 3 shows a section of the field and armature corresponding to the usual direct-current motor, or an alternating-current motor without compensating winding. In the direct-current motor the armature ampere-turns lying under the pole face tend to set up a local field around themselves, producing what is known as cross-induction. This produces no harmful effect except in crowding the field induction to one edge of the pole, thus shifting the magnetic field slightly and possibly affecting the commutation in a small degree. But if the armature is carrying alternating current this cross flux will generate an electromotive force in the armature winding, and this will be added to the field self-induction, thus increasing the self-induction or choking action of the machine.

As the armature turns on such motors are much greater, in proportion, than the field turns, it is evident that the ampere-turns under the pole face can exert a relatively great cross-magnetizing effect. This high cross-magnetization generates a high armature self-induction which may be almost as much as the field self-induction. Further, this great cross-induction would tend to shift the magnetic field quite appreciably, thus affecting the commutation to some extent.

To overcome this serious objection, the neutralizing winding is added. This is a winding embedded in the pole face and so arranged that it opposes the armature cross-magnetizing action. The arrangement is shown in Fig. 4. As it opposes and thus neutralizes the cross-induction set up by the armature winding, it eliminates the self-induction due to the cross-magnetization. It also prevents shifting of the magnetic field and thus eliminates its injurious effect on commutation. As the cross-flux is practically cut out the armature winding becomes relatively non-inductive. There is, however, a small self-induction in the armature and neutralizing windings, due to the small flux which can be set up in the space between the two windings, they being on separate cores with an air-gap between.
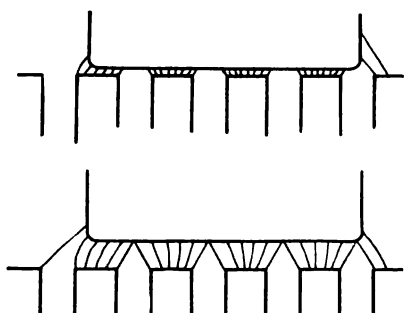
Fig. 5

I have stated that the field turns of the alternating-current motor can only be 20 to 25 percent as many as in ordinary direct-current practice. It may be questioned how the field can be magnetized with so few field turns. This has been one of the most difficult problems in the motor. Obviously, one solution would be the use of a very small air-gap, but in railway practice there are objections to making the air-gap unduly small. Furthermore, if the armature has large open slots, as shown in Fig. 5, experience shows that a reduction in the clearance between the armature and field iron does not represent a corresponding decrease in the effective length of the air-gap, due to the fact that the fringing of the magnetic flux from the tooth tip of the pole face changes as the air-gap is varied. The most effective construction yet used consists in making the armature slots of the partially closed type as in the secondary of an induction motor. This is shown in Fig. 6.

With this construction practically the whole armature surface under the pole becomes effective, and the true length of air-gap is practically the same as the distance from iron to iron. With the increased effective surface, due to this construction, the length of air-gap need not be unduly decreased, which is of considerable importance in railway work.

A further assistance in reducing the required field turns is the field construction used in the single-phase motor. The magnetic circuit consists of laminations of high permeability and usually without joints across the magnetic path. The iron is also worked either below the bend in the saturation curve or, at most, only slightly up on the bend, except in the case of very low frequency motors where more field turns are permissible. Taking the whole magnetic circuit into account, on 25 cycle motors about 80 percent of the whole field excitation is expended in the air-gap, while in direct-current motors, even with a much larger air-gap, as much as 40 to 50 percent of the magnetization may be expended in the iron and in the joints.
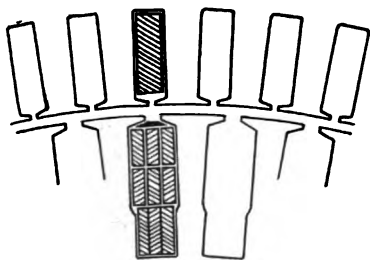
FIG. 6

This armature construction with the partly closed slots has been found very effective in large, slow-speed, single-phase motors in which a relatively large number of poles is required. This construction is used on the New Haven 250 hp., 25-cycle motors; also on the 500 hp., 15 cycle motors on the locomotive which was exhibited at Atlantic City at the Street Railway convention, October, 1907. Geared motors for interurban service can be constructed with ordinary open slots with bands, and many have been built that way. The semi-closed slot, however, allows more economical field excitation.

It may be asked what the objection is to low power-factors on single-phase railway motors, aside from the increased wattless load on the generating station and transmission circuits. There is an objection to the low power-factor in such motors, a very serious one. This lies in the greatly reduced margin for overload torque in case the supply voltage is lowered. In railway work it is generally the abnormal loads or torques which cause a reduction in the line voltage; that is, the overload decreases the trolley voltage just when a good voltage condition is most necessary. This is true

of direct current as well as alternating current. In the direct-current motor, however, such reduction in voltage simply means reduced speed, but in the alternating-current motor the effect may be more serious.

To illustrate, assume a motor with a power-factor of 90 percent at full-load. The energy component of the input being 90 percent, the inductive component is about 44 percent or, putting it in terms of electromotive force, the inductive volts of the motor are 44 percent of the terminal voltage. Neglecting the resistance of the motor, a supplied electromotive force of 44 percent of the rated voltage would just drive full-load current through it and develop full-load torque. With full voltage applied the motor could develop from five to six times full-load torque. Under abnormal conditions a drop of 30 percent in the line voltage would still give sufficient voltage at the motor terminals to develop two and one half to three times full-load torque. Considering next a motor with 80 percent power-factor at full-load. The inductive voltage would then become 60 per cent of the terminal voltage, and therefore 60 percent of the rated voltage must be applied to send full-load current through the motor. This neglects the resistance of the motor, which, if included, means that slightly more than 60 percent of the voltage is required. With full voltage applied, this motor would develop about three or four times the rated torque. With 30 percent drop in the line voltage the motor could develop from one and one half to two times rated torque, which is hardly enough for an emergency condition.

Taking, next, a motor with 70 percent power-factor, at full-load it would require 70 percent of the rated voltage to send full-load current through the motor; with 30 percent drop in line voltage the motor could just develop full-load torque, and even with 15 percent drop it would develop only about one and one-half times rated torque. As 15 percent drop is liable to occur on any ordinary system, this latter motor would be a very unsafe one.

It is evident from the above that it would be bad practice in railway work to install motors with very low full-load power-factors. In general, the higher the power-factor the more satisfactory will be the service, other things being equal.

I have endeavored to explain some of the problems which have been encountered in the design of single-phase commutator railway motors of sizes suitable for all classes of railway service. Here is a type of machine which has been known for a great many years,

but which, until the last few years, has been considered utterly bad. In a comparatively short time it has been changed from what was considered an unworkable machine to a highly satisfactory one and this has been accomplished, not by any radically new discoveries, but by the common-sense application of well known principles to overcome the apparently inherent defects of the type. As an indication that the motor is making progress in the railway field, I will mention that the first commercial single-phase railway motors have not been in use more than four or five years, and yet at the present time there have been sold by the various manufacturers in this country and Europe, a total capacity of approximately 200 000 to 250 000 hp., a very considerable part of which has been put in operation. Considering that the motor was a newcomer in a well established field, the above record is astonishing. However, it may be safely predicted that what has been done in the last five years will hardly make a showing compared with what will be done during the next five years, for the real field for such motors, namely, heavy railway work, has hardly been touched.

AUTOMATIC CONTROL OF DIRECT-CURRENT MOTORS IN INDUSTRIAL SERVICE

D. E. CARPENTER

THE ease and accuracy with which electric motors can be started and the speed controlled, as well as their superior economy, are among the most important causes for the rapid extension of the use of electric motor drive in industrial operations. No small part of the success of electric motors has been contributed by the motor control devices; in fact, for many purposes the successful application of the motor has been delayed until a suitable controlling device could be obtained.

Motor starters and controllers are now available, or can be readily devised along standardized lines, for almost every conceiv-
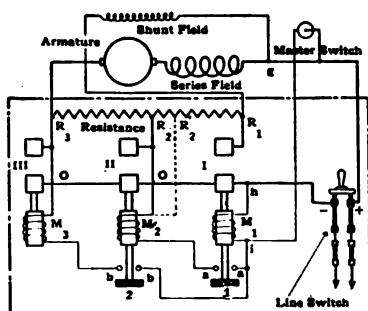
FIG. 1—CONNECTION DIAGRAM, AUTOMATIC MAGNET SWITCH CONTROLLER
Acceleration by Drop in Resistance
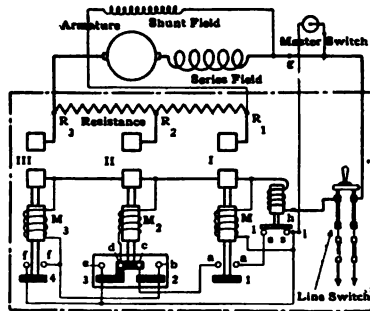
FIG. 2—CONNECTION DIAGRAM AUTOMATIC MAGNET SWITCH CONTROLLER
Acceleration by Series Relays

able service for which a motor can be installed; and the selection of the proper device is a problem requiring the most careful thought. This problem may be;

1—To start, stop, and possibly to reverse the motor either manually at the will of an operator, or automatically at fixed limits in the changing conditions that the motor is employed to govern, as a changing liquid level or a changing pressure.

2—To regulate or adjust the motor speed.

These two general processes may be so combined that, under a given set of conditions, the motor will automatically perform a predetermined series of operations. Any of the control processes may

be performed from a point near the motor or from a distant point more convenient for the operator or for the installation of an automatic master controller.

Starting an electric motor is very similar to starting any other mechanical device. To overcome the inertia of the moving parts of the motor and the apparatus it drives requires a considerable supply of energy, and the change from a condition of rest to full speed requires appreciable time. The instant application of an uncontrolled current to the idle motor would produce results in some respects similar to starting a steam engine by instantly throwing the throttle valve wide open. Unless the motor is very small, the sudden shock would endanger the apparatus. The motor, moreover, would be in no condition to resist the absorption of a large quantity of energy and might be injured, or the voltage of the circuits from which the energy is drawn might be seriously disturbed. All except very small motors, therefore, must be started and accelerated by admitting the driving energy by steps, or increments. In case of direct-current motors, this is accomplished by using a resistance to check the initial flow of current and then cutting the resistance out of circuit, or short-circuiting it, in sections as the motor speed increases. The various forms of motor starting devices are merely different means of inserting and removing from the motor circuit this starting resistance.

Fig. 3—Accelerating Relay, Overload Relay, or Limit Switch

Resistance designed solely for starting purposes is proportioned to carry the motor current during only the short time necessary to . bring the motor up to full speed. If this time is continued too long, the starting resistance may be injured by overheating; if too short, the motor will take too much current and may be injured or the voltage of the supply circuits may be reduced by the excessive I R drop. Starting a motor with a manually operated starter is therefore a somewhat delicate process requiring some skill and care on the part of the operator.

For these reasons, a motor starter by which the rate of motor speed acceleration can be predetermined, and which will always operate automatically in the same time, or so as to maintain approxi-

mately the same starting conditions on the motor, has a considerable advantage over a manually operated starter. Less skill and thought are required of the operator, and there is greater assurance against mistakes. Moreover, the automatic starter can be placed near the motor and operated from any convenient point by means of a master switch connected with the controller by two small wires.

Mechanically, the best controller is the one that will operate for the longest time with the least expense for repairs. Substantial construction, the ability of the wearing parts to withstand for long periods the service conditions, their simplicity and ease of renewal when worn out—all are points requiring consideration in the selection of a controller.

Various types of automatic motor starters and controllers have been developed, consisting of one or more electro-magnetically operated switches, so electrically interconnected with suitable starting or controlling resistances and with the motors, that the recurrence of given starting conditions is always followed automatically by a certain predetermined operation of the switches and a corresponding action of the motors. The accompanying description and illustrations apply to a type of magnet switch controller which has met with considerable success in service.
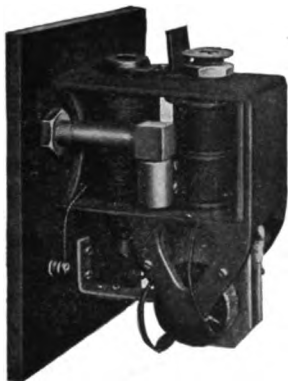
FIG. 4 — CIRCUIT - BREAKER RELAY WITH RESET COIL

The current required to operate the magnet switches is very small and may be controlled manually or automatically by means of a switch mounted either on the front of the panel or at any other convenient point remote from the panel. For most purposes only two small wires are necessary between the controller and the master switch. On closing the master switch, the magnet switches close automatically in a regular sequence, the time interval between the closing of any switch and that of the next depending on the motor current. Referring to the magnet switch units by number in the order of their closing, when starting a motor, the first closes the circuit through the motor armature with all the starting resistance in series. The motor starts with comparatively high current which decreases as the speed accelerates. When the starting current has dropped to a predetermined

value the second magnet switch closes and short-circuits a section of resistance. This action is followed by another impulse of current which again decreases as the speed continues to increase. When the current has fallen to the limit at which the third switch is set to operate, another section of resistance is automatically short-circuited, and so on until all the magnet switches are closed, all the resistance is cut out or short-circuited, and full speed is attained.

By predetermining the rate of acceleration for the service conditions, excessive starting currents are avoided, and the motor, the supply circuits, and all connected apparatus are automatically protected against carelessness or ignorance in manipulating the motor starter. Automatic safety devices also give protection against momentary failure of power supply and against overloads. Powerful blow-out magnets are provided to protect all contacts where a circuit carrying any considerable current is to be opened.

The lag in the operation of the switches, which governs the rate of acceleration of the motor, is controlled by either of two methods:

FIG. 5—CONNECTION DIAGRAM, CIRCUIT-BREAKER RELAY WITH RESET COIL

1—By the varying drop of voltage in the starting resistance.

2—By means of a series accelerating relay switch.

These methods will be understood by reference to Figs. 1 and 2. These diagrams are made to show the connections in the simplest possible manner and for purposes of explanation of general principles only; the controllers have some interlocking contacts not shown in the diagrams.

In both diagrams are shown compound wound motors connected to three-point starters. Each starter has three magnet switches energized by coils *M*. The main contacts *I, II, III* are above the magnet coils and the interlocking contacts by which the sequence of operation of the magnet switches is determined are below. In each diagram the master switch can be located remote from the motor and controller. The line switch does not directly control any of the motor or starter circuit; not until the *master* switch is closed, therefore, do the operations begin.

ACCELERATION BY DROP IN RESISTANCE

Closing the master switch in Fig. 1 connects magnet coil M_1, across the circuit; the magnet is energized, its core rises, main contacts I are closed, and interlocking contacts a-a are bridged by contact I. Main contacts I connect the shunt field directly across the main circuit and close the circuit through the series field, armature and starting resistance R_3 R_1. The motor starts, and the high starting current causes a considerable drop of voltage in the starting resistance.

The coils M are wound for full line voltage, except that for higher than 220 volts, 220-volt coils with resistance in series are used. It is evident that the promptness with which the magnet switches act depends largely on the voltage applied to the coil terminals. For example, 180 volts will cause a 220-volt switch to close much more slowly than will the full 220 volts.
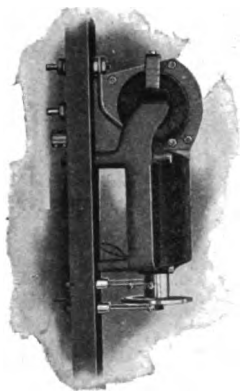
FIG. 6—AUTOMATIC MAGNET SWITCH UNIT—250-AMPERE CAPACITY

When contact I bridges contacts a-a, the operating circuit coil through M_2, and resistance R_2 R_1 is closed. The coil is then subjected to full line voltage less the drop in resistance R_2 R_1. While the starting current is high this voltage drop is considerable, and the closing of the second magnet switch is thereby delayed until the motor current has fallen to a strength that can be approximately predetermined. The operation of the second magnet switch closes contacts II and bridges contacts b-b by contact 2. Contacts II short-circuit resistance R_2 R_1 and the bridge across b-b closes the circuit throug coil M_3 and resistance R_3 R_2. When contacts II close, the starting current increases momentarily and on account of the voltage drop in resistance R_3 R_2, the closing of the third magnet switch is delayed in the same manner as described in connection with contacts II.

This lag in the operation of the accelerating magnet switches can be adjusted by changing the connection point of the coils M_2 and M_3 to the resistance. For example, if coil M_2, Fig. 1, were connected to point R'_2, as shown by the dotted line, there would be less resistance in series with the coil, and consequently higher voltage would be applied to the coil terminals. The nearer the connection

points of the terminals of coils M_2 and M_3 are to the negative end of the resistance R_1, the less will be the voltage drop affecting the operation of the second and third magnet switches. If both these coil terminals were connected to R_1, or to the negative side of the circuit at points $O\ O$, coil M_2 would receive full voltage as soon as contacts a-a are bridged and coil M_3 as as soon as contacts b-b are bridged. The three magnet switches would then close in quick succession, the delay in the operation of the second and third switches being only that caused by their own time element.

This time element is effective, of course, in any case; but if no other delaying element is introduced the acceleration will be very rapid, the starting current high, and the tax on the motors severe.
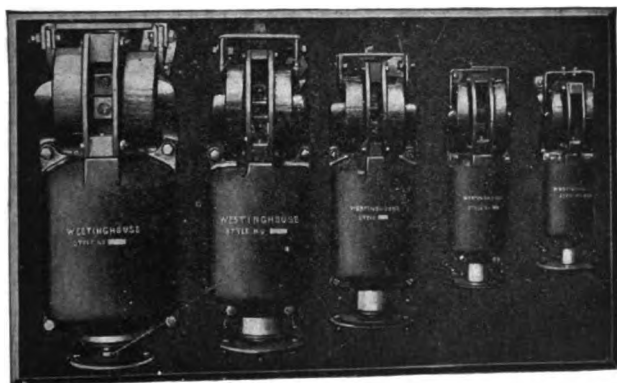
Fig. 7—Automatic Magnet Switches
Capacities: 1000, 500, 350, 250, and 100 Amperes.

ACCELERATION BY SERIES RELAY

With connections as shown in Fig. 2, magnet coil M_1 is energized and its core lifted as soon as the master switch is closed. Contacts I close and the motor starts. At the same instant contact I bridges the gap a-a in the circuit of coil M_2. The high starting current, however, causes the relay switch to open the gap s-s also in the circuit of coil M_2. As soon as the starting current has fallen to a limit predetermined by the relay adjustment, the relay core drops, and gap s-s is closed. The second magnet switch then operates, simultaneously closing contacts II, bridging gap b-c by contacts 2, and opening gap c-d and closing gap d-e by contact 3.

Contacts II short-circuit resistance $R_2\ R_1$ causing an increase

in the motor current, and the relay switch again opens gap *s-s*. But the opening of gap *c-d* and the closing of gap *d-e* has, meanwhile, connected coil M_2 across the circuit independently of gap *s-s*; so that while the relay switch can delay the closing of a magnet switch, it has no control over one that is closed. Gaps *a-a* and *b-c* being bridged by contacts *1* and *2*, respectively, the circuit through coil M_3 will be closed as soon as the motor current has decreased enough to
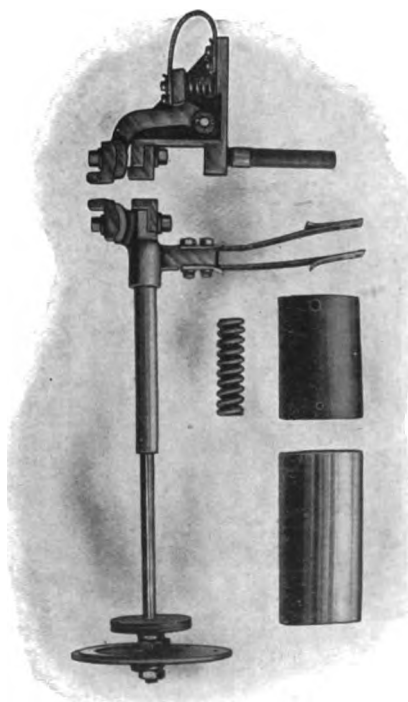
Fig. 8—Principal Parts   Fig. 9—Cross Section
Magnet Switch Unit—500 Ampere Capacity
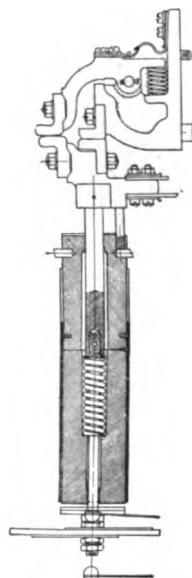
allow the relay switch to drop back and close gap *s-s*.

As soon as coil M_3 is energized, contacts *III* are closed, and gap *f-f* is bridged by contact *4*. Contacts *III* connect the motor directly across the circuit and the bridge across gap *f-f* removes coil M_3 from any further control by the relay switch.

CHOICE OF METHOD

The method of controlling the rate of acceleration by drop in resistance is simple, effective, and perfectly satisfactory where the

voltage of the supply circuit is fairly steady. Acceleration by time element of the switches alone is useful where very quick starting is required, as in some operations in steel mills and rolling mills. Acceleration by series relay is essential where the line voltage fluctuates; by this method very close results can be obtained.

SAFETY DEVICES

In a complete magnet switch controller of the type under consideration every avenue through which any injury might come to any of the connected apparatus or circuits is guarded by an effective safety device. If the voltage fails momentarily the magnet switches drop open, thus giving protection when the power returns.

For some kinds of service an overload relay or limit switch, the same in construction as the accelerating relay, is so connected in
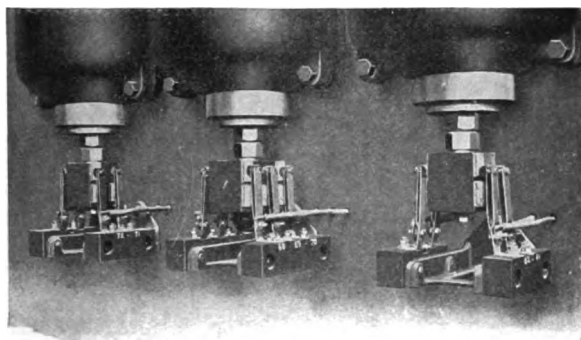
FIG. 10—INTERLOCKING CONTACTS, AUTOMATIC MAGNET
SWITCH CONTROLLERS

the motor circuit that in case of temporary overload all the magnet switches, except the first ones, drop open. The motor armature then continues to rotate slowly with all resistance in series until the overload is removed, after which it accelerates, as in first starting, to full speed. This device is useful with a motor operating an excavating shovel. When the shovel strikes a boulder, the aramature resistance is automatically cut into circuit. The motor operates at slow speed until the obstruction is passed and then regains its full speed.

When necessary, a circuit-breaker relay with a reset coil and blow-out magnets is supplied. This relay opens all the magnet switches and completely disconnects the motor from the supply circuit in case of a dangerous overload. The connections of the cir-

cuit-breaker relay are shown in Fig. 5. The letters *C.B.* signify circuit-breaker; *B.O.*, blow-out; and the letters *g, h,* and *i* signify connecting points as indicated in Figs. 1 and 2, showing how the circuit-breaker relay would be used in connection with either of those diagrams.

With this relay in circuit, a dangerous overload opens the motor circuit at once, the blow-out coils promptly disrupting the arc across the gap where the relay opens the control circuit. The magnet switches immediately drop and open the motor circuit. The break in the motor circuit occurs between arcing tips protected by heavy blow-out coils.

When the circuit-breaker relay opens, it is automatically locked and held open until the reset switch is closed and the reset coil thereby energized. This locking device prevents the motor from starting automatically, and gives an opportunity to remove the overload.

MAGNET SWITCHES

The magnet switch unit consists essentially of one or more sets of contacts operated by an electro-magnet. The unit is so mounted that the plunger operates vertically, being raised when the coil is energized and dropping back by force of gravity assisted by springs when the coil

Fig. 11—MASTER SWITCH
Interior View.

is de-energized. The main contacts are above the magnet coil; they are closed when the plunger is raised and opened when the plunger drops. The interlocking contacts are below the magnet coil.

These magnet switches are built in standard capacities of 1 000, 500, 350, 250 and 100 amperes. By proper selection and grouping, an automatic starter or speed controller can be built for a motor of any capacity, from a small one requiring a single magnet switch for starting purposes only, to a very large motor requiring many switches for starting and accelerating, for controlling the speed, for reversing, etc.; also for any class of service, such as driving elevators, pumps, hoists, cranes, machine tools, etc.

Magnetic blow-out coils protect each set of contacts between which, without such protection, injurious arcing might occur. This protection is not always required for those contacts used only for short-circuiting sections of resistance. The magnetic field for disrupting the arcs is the resultant of those produced by two coils— one on each side of the contacts, by which the arc is forced quickly to the front and blown out. Slate arc shields protect the blow-out coils.

The main contacts are of the butt-joint type, the lower portion being moved by the plunger and the upper portion being fixed to the panel either rigidly or with a slight spring motion. In all except the smallest size the main contacts are double, one part, called the arcing tip, breaking contact slightly after the other. The arcing tips are brass, and the other main contacts are copper. Both parts lie in the field of the blow-out magnets. These contacts have demonstrated their ability to withstand long and severe service, and moreover, their extreme simplicity makes them easily renewable in any repair shop when worn out.

Fig. 8 shows some of the principal parts of a 500-ampere magnet switch unit and Fig. 9 is a sectional drawing showing how the parts are assembled.

In all cases the contacts close against springs, which act as cushions to take up the wear, and also assist gravity in accelerating the downward movement of the plunger, thus giving quick and positive opening of the switches.

For ordinary service the interlocking contacts consist of flat brass rings, carried on insulating discs at the lower ends of the plunger rods, the rings abutting against copper fingers projecting from the panel. For heavy mill service, contact strips and fingers are mounted on fibre blocks attached to the plunger rods and the panels respectively, as shown in Fig. 10. Since all interlocking contacts carry only the very small magnet exciting current they are made comparatively light.

The master switch serves to close and open the circuit carrying the operating current of the magnet switches; since this current is very small, the parts of the master switch are no heavier than is required for substantial mechanical construction. In its simplest form the master switch is essentially a double-break single-pole, single-throw snap switch connected to the controller by two wires of small, the parts of the master switch are no heavier than is several contacts in succession and requiring more than two connect-

ing wires, or a switch of the reversing type is supplied. The master switch is either entirely enclosed in a cast iron box, the cover of which is easily removed to give access to the working parts, or is of the open type, according to the conditions of service. This switch is usually mounted remote from the controller.

The panel is made large enough to carry the magnet switches and auxiliary devices, such as a knife switch, fuses, relay switches, etc., when any of these are necessary.

PROTECTIVE RELAY SWITCHES

The series accelerating relay switch and the overload relay switch are constructed along the same lines as the magnet switch units, but with lighter contacts, since these contacts carry only the small energizing current of the magnet switches.

The circuit-breaker relay has two magnet coils, one in series with the motor circuit for tripping the circuit breaker in case of overload, and the other for resetting the circuit breaker by releasing the locking device which holds it open. The construction is similar to that of the magnet switch units. In the upper end of the series coil is a stationary core so arranged that the air gap between it and the movable core can be varied to adjust the current at which the circuit will be opened. The plunger carries a latch piece and a renewable contact tip at its lower end. When the plunger rises, a trigger catches the latch in the raised position and holds it until the reset switch is closed. When the reset coil is energized its plunger is moved against the action of a spring that tends to return it ready to catch the main plunger again. The switch for closing the circuit of the reset coil is of the push button type and normally remains open.

FRICTION BRAKES

HENRY D. JAMES

THE increasing application of electric motors to hoisting machinery has brought to the active attention of engineers the question of the best means of slowing down and stopping these motors. Brakes for this purpose are of two general types— friction brakes and dynamic brakes. The latter must generally be supplemented by friction brakes as the dynamic braking ceases, when the motor comes to rest and the load may drift if not held by a friction brake. The writer described a new form of friction brake for direct-current motors in the May, 1908, issue of the JOURNAL. More recently Mr. H. A. Steen presented a paper before the Engineers' Society of Western Pennsylvania on the general subject of friction brakes. Mr. Steen made an effort to obtain descriptions of brakes from the leading manufacturers in this country and abroad. The wide variety of designs in use indicates a very unsettled condition as to the arrangement of the fundamental parts. A great variety of friction materials is used and every known method of applying them is indicated.

In discussing friction brakes, three fundamental facts should not be lost sight of :—

1—The brake must radiate in the form of heat all the energy that it absorbs while performing its cycle of work. The amount of heat absorbed has practically nothing to do with the design of the brake or the friction material. The operating temperature of a brake depends entirely upon the facilities for radiating the heat. A brake can be considered as a machine for converting the kinetic energy of the moving parts into heat. This heat must be disposed of in the same way as is the heat in a motor. If the friction material is of a kind that will be destroyed if subjected to a high temperature, then more friction surface must be used to keep down the work per square inch than would be necessary with a friction material permitting several hundred degrees rise in temperature. A brake in which such a friction material is used may be made much smaller for the same reason that a motor insulated with mica and asbestos can be made smaller and operated at a higher temperature than one insulated with cotton and treated cloth.

2—The torque exerted by the brake at the instant of application must not be greatly in excess of the normal torque of the motor,

otherwise the shaft may be injured. The excess of torque at the instant of application is due to the stored energy of the moving parts of the brake. This is most noticeable where the brake is applied by a weight and the torque is obtained by this weight acting on the friction surfaces through a system of levers. To release the brake, the weight is lifted. When the brake is applied, the weight falls several inches so that when the friction surfaces come together, this weight has considerable velocity and the surfaces are clamped together with much more than normal force. Under such conditions, the shaft should be much stronger than would be necessary to transmit the normal torque. Various methods are used to overcome this defect, such as dashpots, or the substitution of a spring for the weight. In a good design all of the moving parts are considered and practically all of their "hammer blow" effect is eliminated. Other designs simply make the shaft and wheel strong enough to stand the shock. In designing very small brakes, this feature may be neglected, but the larger the brake, the more important this factor becomes.

3—The friction material should, as for as possible, be free from the influence of external agencies. Friction surfaces that depend upon lubrication may be destroyed by its absence or may grip so tight that the shaft is injured. Surfaces not intended for lubrication may be run so hot that any lubricant would be immediately vulcanized. If dirt or grit injures these surfaces, they should be covered up even though this may make them slightly less easy to inspect. A good friction material should be able to withstand considerable abuse and still operate properly.

In examining a brake, the above points should be considered; stated briefly they are:—

1—Its ability to stand high temperatures and to radiate heat.

2—Its freedom from hammer blow or shock when applied.

3—The durability of the friction surfaces.

The diversity in design of commercial brakes is due primarily to the desire to obtain the required torque with as small a magnet as possible.

It is well known that such materials as leather, cork, etc., exert a large tractive force on a brake wheel with light pressures. There seems to be a clinging effect which diminishes under heavy pressures, so that at considerable pressure the coefficient of oiled cork on cast iron is about the same as cast iron on cast iron dry. At light pressures, cast iron has a tendency to glaze and materially re-

duce the friction. Large brake wheels may frequently be seen operating with leather or cork lined shoes at small pressures. The small pressure is necessary for the life of the lining, otherwise it would be charred by heat.

The great variety of mechanical movements in use is partly due to the necessity of multiplying the leverage between the magnet and the friction surfaces, and partly for convenience in adapting the design to the particular application. Large low pressure brakes are generally noiseless in operation, but very bulky in proportion to the torque developed. To figure the leverage between the magnet and the friction surfaces, take the ratio of the work done by the magnet (pounds pull $\times$ inches travel) to the work done on the friction surfaces (pressure $\times$ travel of shoes or band). No change in the
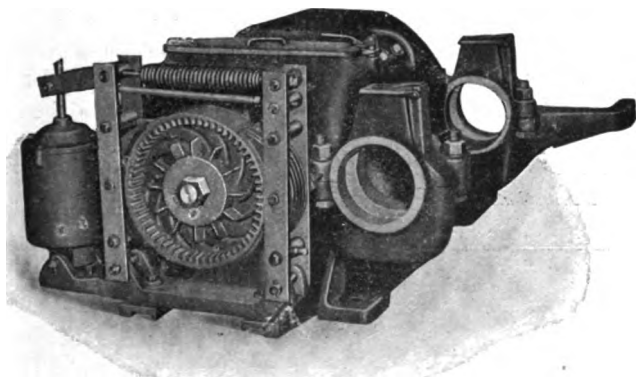
Fig. 1

arrangement of levers will enable one to use a smaller magnet to do the same work. A change in the principle of the brake, such as using a band brake instead of a shoe brake, will often help. But to take the same brake and rearrange the levers will not reduce the foot-pounds of work required of the magnet. To illustrate this point, in the previous article a type of brake was described in which the levers were arranged to give less pull at the beginning of the magnet travel than at the end. See Fig. 1. This arrangement assists in reducing the size of the magnet. If this system of levers could be altered to give a still greater ratio between the initial and final pull without increasing the travel, it might be possible to still further reduce the size of the magnet as it would make greater use of the increasing pull of the magnet at shortened air-gaps. If,

however, the pull on the magnet were one-half the present and the travel twice as great, the foot-pounds of work remains constant. For the reason, therefore, that the foot-pounds of work done by the magnet remains the same for a given amount of work delivered to the friction element, there is little choice between the different systems of levers from an efficiency standpoint. The choice of design lies rather in the direction of simplicity and durability.

A brake operated upon another principle is shown in Fig. 2— the band brake. It is a well known fact that the pull on the end of a brake band towards which the wheel is turning is much less than on the other end. If the magnet pulls on the low tension end of the band and the opposite end is anchored, the magnet may be small compared with the torque exerted. A non-reversing brake of this kind may be easily designed, the difficulty comes with a reversing brake. To obtain equally favorable conditions, the anchorage must be automatically shifted from one end to the other. This is accomplished in the brake shown in Fig. 2 by mounting the brake beams and
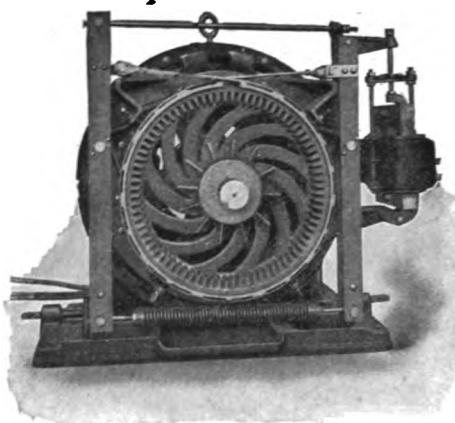
Fig. 2

magnet upon pivots. The torque of the brake shifts this system of levers towards the direction of the rotation, until the beam, to which is anchored the high-tension end of the band, strikes a stop on the supporting frame. The other end of the band is then free to be operated on by a spring. As the angle of contact between the wheel and the band is nearly 360 degrees, only a slight pull is required on the free end of the band to give a heavy torque. The result is that only a small spring and a small pull is required of the magnet. The magnet travel is short, as a very small clearance between the band and the wheel is sufficient. This is the result of a special feature in the construction of this band. The wearing surface is made from a cast iron ring turned to a slightly larger diameter than the wheel, and then split. Outside of this ring is a steel band, A series of set screws adjusts the clearance at different parts

of the circumference. When the tension is removed from the band, this ring springs out uniformly and true to the wheel, so that a running clearance is easily obtained. The "hammer blow" effect is eliminated by providing a lost motion connection between the magnet plungers and the levers.

This brake is well adapted to alternating-current magnets, as it reduces the work required by the magnet to a minimum. It is not quite so simple and so readily repaired as the shoe brake previously described, which is preferable where direct current is available. The band brake just described fulfills the conditions laid down in the first part of this article and is a good example of a brake adapted to an alternating-current magnet. Commercial conditions may make it more desirable than the shoe brake for certain applications where direct current is available.

In this article, the writer has endeavored to show that a friction brake should be designed and applied as carefully as a motor. The work that the brake is to do should be clearly outlined and the characteristics of the machinery to which it is attached should be stated. A brake suitable for a crane will not do for a passenger elevator. If the load is to be lowered a considerable distance, some method of artificial cooling may be necessary such as the use of water. Wherever possible brakes should be mounted on the motor shafts, as their size is determined by the torque only, and if a brake is run at a lower speed than the motor, it must be correspondingly larger.

In a future article the writer intends to describe some of the methods used for dynamic braking, as many applications require both the friction brake and the dynamic brake.

ALTERNATING-CURRENT INSTRUMENTS—I

DISC TYPE INDUCTION AMMETERS AND VOLTMETERS

PAUL MacGAHAN

NOTE—The following article describes a form of indicating instrument which, although at present superseded by other forms, has been manufactured and installed in large numbers. As such instruments are in active service to-day, and technical questions are continually being asked by those who are using them, the descriptive matter regarding their construction and principles of operation will be appreciated. The presentation of the characteristics of the instrument and all reasons which led to its adoption and to its being superseded, form an interesting chapter in the development of electrical apparatus.—(Ed.)

THE serious problem which confronted the electric meter engineer when he attempted to design meters for use on alternating-current circuits was presented in an editorial on "Progress in Instrument Design" in the JOURNAL for August, 1905. Various types of instruments have been developed to meet the variety of requirements presented in the operation of alternating-current systems; some have been superseded by more satisfactory types; others have undergone various modifications to improve their operation or simplify their manufacture.

The disc type induction ammeters and voltmeters of Westinghouse manufacture were brought out in 1898 and 1899, in the form shown in Fig. 1. The movement consisted of an aluminum disc with a spiral-shaped outline which was mounted on a shaft to which was also attached the pointer and the hub of the controlling spring, as shown in the interior view of the ammeter, Fig. 2, in which the pointer and spring are omitted. The disc was driven by means of an electromagnet in the air-gap of which it was free to move. The pole pieces of the electromagnet were provided with "shading" coils, in other words, the half of each pole piece on the side toward which rotation was to be produced was surrounded by a heavy band of copper in which secondary currents were induced, thus producing a magnetic phase displacement and a "shifting magnetic field. In the ammeter the magnet coil was shunted by a non-inductive coil of copper wire as shown at A-A in Fig. 3, so designed as to partially compensate for the frequency and temperature errors. In the voltmeter this compensation was effected in a similar manner for 25 cycles, and by a secondary short-circuited coil on the pole piece for 60 and 133 cycles.

The elementary principle underlying the operation of the meter

is a very simple one. The slotted faces of the electro-magnet provided with shading coils produce a shifting magnetic field. This shifting magnetic field induces currents in an adjacent disc and the reaction between these currents and the shifting field produces a

torque tending to rotate the meter disc. There are, however, some features of this simple action which are not suitable for a commercial measuring instrument and which rendered necessary certain auxiliary features which were incorporated in the meter. These elements are the following:

1—The torque tending to move the disc varies as the square of the current, which requires a scale of unequal divisions instead of equal divisions as is often preferred.

FIG. 1—DISC TYPE INDUCTION AMMETER

2—The elements producing torque vary with the frequency, hence the indications of the meter would be affected by the frequency as well as by changes in the current.

3—An increase in temperature increases the resistance of the disc, reduces the induced current and consequently the torque is reduced. This gives rise to temperature errors which are not admissible in a commercial instrument.

These several fundamental conditions have been obviated or compensated for by means of relatively small modifications in the design and construction of the instrument. The torque normally varies as the square of the current through the instrument. The torque may be varied by altering the amount of the disc which comes within the magnetic field in different

FIG. 2—INTERIOR VIEW OF METER SHOWN IN FIG. 1

angular positions of the disc. For example when the current is doubled, the torque would normally be four times as great if the section of the disc were the same. The disc may be cut away so that the portion of the disc which is within the field when the greater current is

flowing will be such as to produce a reduced torque and hence, with a disc of the proper shape, a torque may be produced which is directly proportional to the current, thereby giving a deflection proportional to the current when the motion of the disc is balanced by an ordinary spring. A spiral shaped outline was found to give the desired law of torque and deflection of disc and was adopted as shown in the view of the disc of an ammeter in Fig. 2.

The correction for frequency was secured in a simple and ingenious way. In the ammeter the magnetizing coil is wound upon an iron core and is so proportioned that its resistance is very low and its inductance is relatively high. A non-inductive resistance, shown at *c* in Fig. 3, is connected in shunt to the instrument coil *b*. The circuit is, therefore, divided into two branches, the resistance of one of which is almost wholly inductive, while the other is purely ohmic. At normal frequency the current will divide in a certain proportion between the two branches. If the frequency increases then a larger proportion will flow through the resistance path and a less proportion through the inductive path, thereby
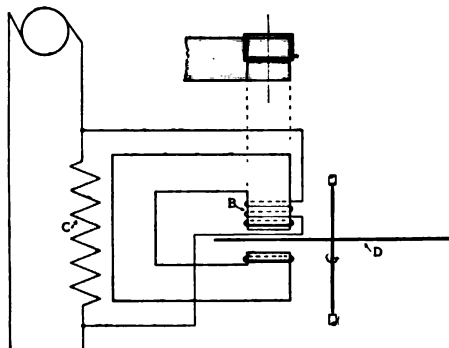
FIG. 3—CONNECTION DIAGRAM AND OUTLINE SKETCH SHOWING PRINCIPLE OF OPERATION OF AMMETER

lessening the current in the meter coil. This reduced current, however, will be more effective in producing torque on account of its higher frequency. By proper proportioning, the two effects are made to balance one another so that over a considerable range of frequency a given current in the main circuit of the meter produces the same torque on the disc, thereby compensating the meter for changes in frequency and making its readings practically independent of frequency over a considerable range. These relations may be expressed by a formula and a curve plotted showing the relation between frequency and torque on the disc for any particular meter. Such a curve is plotted in Fig. 4. From this curve it will be seen that up to a certain frequency the reading of the meter will increase very rapidly while above that point the variation is relatively slight

From the curve it will be noted that at a frequency of 30 the variation of the pull on the disc amounts to one-half percent for a change of one percent in frequency and at a frequency of 60 the variation is one-tenth of one percent for a change of one percent in the frequency. The variation is practically the same at a frequency of 80 as it is at a frequency of 60. Between these two limits the change in the torque on the disc is very small. Hence it will be seen that over this range the meter is practically free from errors due to frequency.

The error due to the effect of temperature variation on the resistance of the disc is corrected in a manner similar to the correction for changes in frequency, i.e., in a divided circuit the current is automatically shifted from one path to the other in such a manner as to effect the desired compensation. An increase in temp-
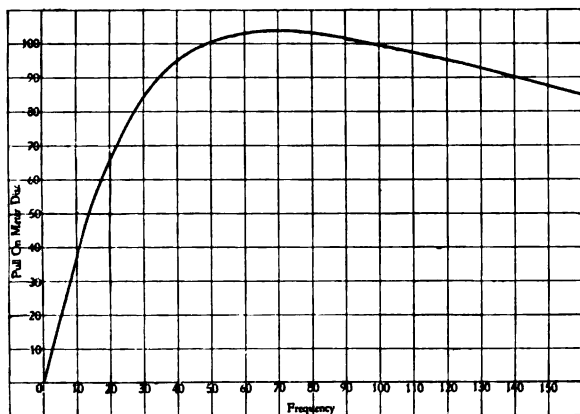
FIG. 4—CURVE SHOWING PERFORMANCE CHARACTERISTICS

erature increases the resistance of the disc, thereby reducing the induced current in the disc. In order to compensate for this, a greater current should flow through the magnetizing coil of the meter. The divided circuit used for effecting the frequency correction as explained above, also serves as a means of correcting for temperature. The resistance circuit which is connected in parallel with the coil is made of material having a temperature co-efficient such that the increase in temperature increases its resistance, thereby throwing a larger proportion of the current through the magnetizing coil of the meter. This increase in current tends to increase the torque, thereby compensating for the reduced current in the disc.

The theoretical values for the frequency and temperature errors

as worked out by formulae are almost exactly checked by results obtained on test. There is in addition, however, a slight heating error due to the unequal heating of the various parts of the meter.

Theoretically, the voltmeter is the same as the ammeter, provided the internal impedance is made small with respect to the total impedance including the external resistance.

In the design of the instrument, one of the vital considerations at that time was the idea of attempting to avoid what is almost one of the "Laws of Nature," that the torque is proportional to the square of the current and that the natural distribution of the scale divisions is derived from this and is therefore proportional to the square of the quantity measured. The attempt was made to overcome this effect by graduating the contour of the disc. As shown in Fig. 5, the scale was made uniform from one-sixth load
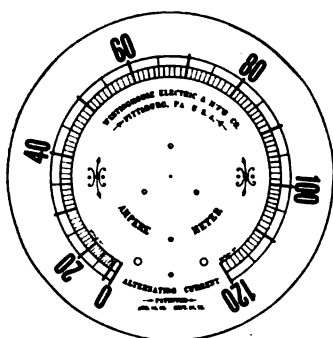
FIG. 5—CORRECTED SCALE—EQUAL DIVISIONS   FIG. 6—NATURAL SCALE—VARYING DIVISIONS
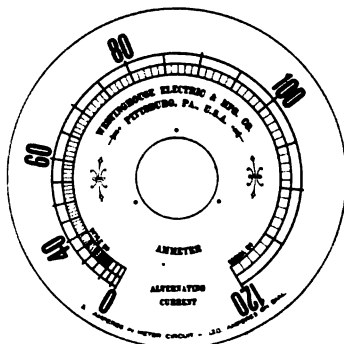
up to full load. In order to get this effect a comparatively large mass of disc metal had to be in the air-gap at low values, and at high values the disc receded almost completely from the pole-pieces. This resulted in an eccentric moving element of comparatively great weight, which necessitated a heavy counter-balancing weight and possessed a low torque per unit weight. The weight was more than a jewel could stand in shipment and hence the meters were shipped with the rear jewels removed and the shaft clamped in place. The attempts of inexperienced operators to replace the jewel was a source of considerable trouble.

As a matter of fact, it has been found that in practical use, little if any advantage is gained in the scale by the graduated disc, as can be observed by comparing Figs. 5 and 6. Over the most important part of the ammeter scale from normal load (two-thirds

full-scale) up, the corrected scale is less open then the "natural" scale, which is proportioned to the square of the current. The very low values up to one-sixth load are no better. The portion from one-sixth load to two-thirds full-scale load is, however, somewhat better, but on the whole the scale cannot be considered more desirable than the natural one. The writer believes that in voltmeters the more open divisions at the normal and over-voltage portions in the natural scale give it a great advantage over the corrected scale. It will readily be appreciated from the above that a great deal was sacrificed in mechanical excellence by attempting to correct the natural scale.

It should be remembered that the above facts did not become apparent to the designers at once; when the disc type meters were brought out there was nothing else as good to be had in the line of alternating-current switchboard ammeters and voltmeters. The general progress of the art and the experience gained in operation and manufacture made it apparent that much better results could be obtained without the scale compensation.

About this time the peculiar form of winding now used in the new induction type meters* was invented by Mr. Frank Conrad. These windings automatically and perfectly correct for any temperature and frequency errors within exceedingly wide ranges, at the same time producing a rotary field. As a drum-shaped movement was found to give a higher torque per unit weight than a disc, and this adapted itself best to a bi-polar form of electromagnet, with a circular core, it was decided to abandon the graduated disc altogether.

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*See description of these meters in the JOURNAL for February, 1907, p. 113.

ELECTRIC INDUSTRY IN GERMANY

WALDEMAR KOCH

TWO nations, the United States and Germany, are leading in the development of the science of electricity as well as in the manufacture of goods based on this knowledge. Each nation practically excludes the other from its national territory. Together they dominate in the world market, which is the only place where sales may be increased even in times when business is slack at home. So it may pay to spend some moments in studying the conditions that developed this industry in Germany, under which our strongest competitor has carefully built up an organization that, through a net of channels, leads their surplus of goods into the hands of the consumers in Europe, South America, Africa and East Asia.

The application of electric current for practical purposes was begun in Germany more than a century ago. But no industry grew up since all engineering was totally undeveloped and the country rather an agricultural one. Even fifty years ago, one would hardly say there was any electrical industry. In 1875 there were eighty-one electrical firms with 1 157 employees, the most important line being apparatus for telegraphing. As a comparison, in the United States seventy-six firms employed 1 271 men. But in the meantime the combined efforts of Pacinotti, Siemens and Gramme had found a way to generate current cheap enough for commercial use. Edison, by his invention of the incandescent lamp, opened a wide field for its application. Larger firms were founded, working on a broad scale from the beginning; the old ones extended more rapidly and the German electrical industry obtained a strong position at home and abroad. Money was cheap, everybody quite willing to risk it in electrical enterprises, such as street railways and central stations, which seemed to guarantee high returns. While in 1883 the shares of only one electrical firm, amounting to $1 250 000, were handled, in 1900 there were 22 electrical corporations listed at the Berlin stock exchange with a capital of $100 000 000 in shares and $65-000 000 in bonds and surplus, the yearly dividends amounting to 11.25 percent on the average for the year or 8.38 percent for the

whole period of eighteen years. 1895 the number of firms pro-
ducing electrical goods was 1 326 which employed 26 320 men.
But only fifteen of them had more than two hundred men each,
only six had a worldwide reputation and these six firms were
practically the masters in the German market as well as in for-
eign countries, as in 1900 $12 000 000 worth of goods were ex-
ported with imports amounting to only $1 600 000. The later
developments and consolidations of these corporations will no
doubt be of interest.

Siemens & Halske—(S. & H.) was founded as early as 1847
by Werner Siemens, an officer of the German army, who turned
out to be one of the most able engineers. His ability made his
firm keep ahead until, at last, owing to the change in conditions
that brought about industrial and commercial success, he was
outrun by Emil Rathenau, an engineer, who, like George West-
inghouse, was at the same time one of the greatest financiers, and
who, although almost seventy years old, still holds his position
as the president of the Allgemeine Electricitats Gesellschaft
(A.E.G.), the largest electrical firm in the world. He became the
owner of the Edison patents for Germany and founded the Allge-
meine Electricitats Gesellschaft in 1883 for their exploitation in
Germany. Later he became independent of the American holding
company and took up all lines of electrical work, except tele-
graphing and telephoning devices, and his firm got ahead of all
competitors. The third firm, Schuckert & Company, was founded
in 1873 by a mechanic who worked in the Edison factory.

The Union Electricitats Gesellschaft started in 1892 and
was practically a branch of the Thomson-Houston Company,
which had a strong position in the construction of electric rail-
ways and transferred the same superiority to its German firm.
A less important firm was the Helios, which bought the alternat-
ing-current patents of Tesla and extended its business when
nearly all the better manufactured products were manufactured
by the firms already mentioned.

The last firm is Lahmeyer & Company, originating in 1893
from a consolidation of two firms in Frankfort.

The following table gives the increase in capital from the
time these firms originated;

SIX LARGEST CORPORATIONS UNTIL 1900

Amount of Shares in Million Marks (1 mark=24 cents)							
	S. & H.	A.E.C.	Schuckert	Union	Helios	Lahmeyer	Total
1890		20			2.2		
1891		20			2.2		
1892		20		1.5	2.2		
1893		20	12	1.5	2.2	1.7	
1894		20	12	1.5	2	1.7	
1895		25	12	3	3	1.7	
1896	35	35	18	3	3	3	97
1897	35	47	22.5	3	8	4	119.5
1898	40	60	28	18	10	4	160
1899	45	60	42	18	16	6	187
1900	54.5	60	42	24	16	10	206.5

Times changed, however, and in 1900 after six years of the greatest prosperity, a crisis occurred in Germany, as sudden and important as the one we have just passed through in the United States. Banks failed, the people withdrew their deposits, money became extremely expensive and all enterprise stopped. The electrical industry had been the center of the rapid development. In 1899, which was, perhaps, the climax, thirty-six percent of the money invested for industrial purposes was required by the electrical line. No wonder that it was the center of depression. One large firm, the seventh in rank, failed and disappeared entirely. Schuckert, in 1902, showed an actual loss of $5 500 000 and a deficit of $4 000 000. The loss amounted to $600 000 with the Lahmeyer Company, to $2 200 000 with the Helios and the Union had gone to the limit of its means.

The weaker firms tried to get help from the stronger ones. They got it by the ambition of the two leading firms, the Allgemeine Electricitats Gesellschaft and Siemens & Halske, to outgrow each other, and their determination to better prices by diminishing competition. The result was that the Allgemeine Electricitats Gesellschaft bought the Union; Siemens & Halske and Schuckert formed the Siemens-Schuckert Werke. Lahmeyer combined with a large cable firm forming the Felton & Guilleaume-Lahmeyer Werke. These three concerns bought the plants of the Helios and simply closed them, thus cutting down the number of large competing firms to three.

The first of these three combinations is of special interest to the United States. The Union, as mentioned before, was a sister company of the Thomson-Houston Company and therefore re-

stricted in its business to only a part of continental Europe. As the Allgemeine Electricitats Gesellschaft, having learned by experience, was not willing to limit its territory, an agreement became necessary with the General Electric Company, the succes· sor to the rights of the Thomson-Houston Company, they made a settlement touching the electrical business in the whole world. Practically all the business of continental Europe came exclusively to the Allgemeine Electricitats Gesellschaft, and the business in the United States and Canada to the General Electric Company. In all other territories, like Africa, South America, etc., a combined working was agreed upon. Besides allowing each other the use of all patents for electric devices, steam turbines, etc., they also consented to exchange all experiences concerning manufacturing and designing. Quite frequently they took advantage of this last allowance and sent over their engineers to study the work of their partner. The result of all this is that to-day there are three dominating concerns left which control a large percentage of the whole business, two of them getting as much as seventy-five percent in some lines. The largest is the Allgemeine Electricitats Gesellschaft. It owns seven large factories around Berlin, one in Russia (Riga) and one in Austria (Vienna). It employs, in average times, about 35 000 men and has a working capital of more than $40 000 000. One hundred and ten branch offices are scattered over the world, principally in Europe. It controls one bank, two holding companies, a number of manufacturing firms, central stations and street railways, and selling and contracting corporations at home and abroad.

The Siemens-Schuckert Werke employs perhaps 25 000 men. They have been and are continually doing very much in systematically developing new lines, especially electro-chemistry. Their organization is as powerful as the one already mentioned. Both are backed but not pulled by the leading German banks. The Felton & Guilleaume-Lahmeyer Werke concentrate their forces more on the national market.

All three concerns have frequently made special agreements and divided up large contracts, giving a part of them to each and helping each other to maintain prices. They employ, all in all, about fifty percent of the men engaged in the electrical industry and have about the same share in the production. Of the other

firms, one, the Bergmann Electricitats Gesellschaft, which at first manufactured nothing but conduits, makes great efforts to secure a share of the trade and has extended its business over a number of branches. Another firm, Mix & Genest, is strong in the telephone business. There are about twenty-seven more corporations and about 250 firms in private hands. Some of them are still important, or even dominant in a special line, but they do business mostly in Germany and never carry out large contracts, either at home or abroad. Often practically all the firms of one line have formed pools or syndicates, for instance, for incandescent lamps which are exclusively sold by the syndicate. For two branches, wireless telegraphy and stationary storage batteries, there are trusts controlled both by the Allgemeine Electricitats Gesellschaft and Siemens & Halske, so that, to some extent, the whole electrical industry is organized for purchasing, producing, contracting and selling.

Germany is a country that covers about seventy-five percent of the area of Texas and has 62 000 000 inhabitants. The German electrical industry employed, in 1906, about 140 000 persons, who produced goods worth nearly $175 000 000. Five hundred million dollars is invested in central stations and electric railways. The exports amount to $33 000 000 strictly electrical products, which is about twenty-five percent of the whole production. The imports were $1 800 000, or six percent of the export.

The census report of the United States gives, for 1905, 784 firms in the electrical line, which employ 71 000 men, have $174-000 000 capital and produce $140 000 000 in products. To these should be added $19 000 000 in electric products made by establishments primarily engaged in the manufacture of other goods.

These figures should not be compared too critically since the statistics are made in different ways and the relation of work, capital and product are different in the two countries.

METER AND RELAY CONNECTIONS—(Cont.)

THREE-PHASE—THREE-WIRE CIRCUITS

HAROLD W. BROWN

SINGLE-PHASE METERS

Either a single-phase wattmeter or a single-phase power-factor meter may be connected as in Fig. 8 to indicate the total power or the power-factor on a three-phase balanced circuit. As a wattmeter connection this is identical in principle with the connections in Fig. 7.* The current circuits have a reversed V-connection, which is equivalent in this case to a delta-connection, since current is to be used in only one current circuit.

Fig. 9 shows another method of making a connection equivalent to that in Fig. 8. In this case the shunt transformers, instead of the current transformers, have a reversed V-connection, this mul-
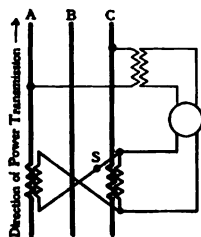
FIG. 8—SINGLE-PHASE
WATTMETER OR POW-
ER-FACTOR METER.
Connections to
three-phase balanced
circuit using one
shunt and two series
transformers.
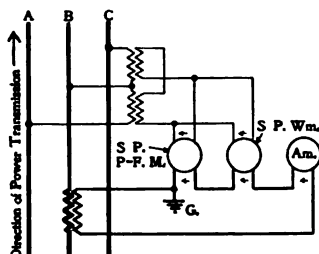
FIG. 9—AMMETER AND SINGLE-
PHASE WATTMETER AND POW-
ER-FACTOR METER ON A THREE-
PHASE BALANCED CIRCUIT

tiplying the e.m.f. by 1.732 and bringing it in phase with the current. A single-phase wattmeter, single-phase power-factor meter and an ammeter are shown in series on the current transformer, and the wattmeter and power-factor meter are connected in parallel on the shunt transformers. All of these meters could have been grouped on the transformers of Fig. 8 with the exception that the ammeter could not be connected directly in series with the other meters, but might be inserted at S to measure the current on one line. The arrangement shown in Fig. 8 is usually preferable to

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*See the first part of the present article in the JOURNAL for December, 1908, Vol. V., p. 731.

Fig. 9 because an extra series transformer costs less than an extra shunt transformer.

Three single-phase wattmeters or power-factor meters may be connected as in Fig. 10 to indicate separately the power or power-factor of each line of a three-phase circuit. The current circuits are connected to Y or V-connected† series transformers, and the voltage circuits to V-connected shunt transformers. The voltage circuits are not, however, connected directly across the shunt transformers, but are Y-connected to these transformers, one side of each meter being connected to one of the transformers and the other side to a common neutral point. In order to have this a true neutral point the resistance of the voltage circuits of the three watmeters should be equal. With a balanced load the three meters would all have equal readings, whatever the power-factor, being different in this respect from the wattmeters connected according to the well-known two-wattmeter method.
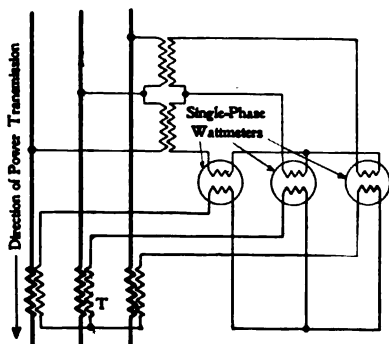
FIG. 10—SINGLE-PHASE WATTMETERS OR POWER-FACTOR METERS

Three single-phase meters connected to indicate the power or power-factor on each line of a three-phase three-wire circuit.

A method of connecting two single-phase wattmeters on a three-phase — three-wire circuit so that with a balanced load the readings on the two wattmeters will be the same at any power-factor is shown in Fig. 11. An important advange of this method of connecting is that neither of the meters will have a negative reading at any power-factor, unless the direction of power transmission is reversed, in which case both meters will have a negative reading. Three series transformers are required for this connection, one being standard and the other two having special windings. If the normal transformer has a five ampere capacity, the transformer on the left should be of this kind ,and the other two should each have 2.5 amperes in the secondary with full-load current in the primary. The shunt transformers connecting to the right and middle lines should have the same ratio of transformation

†Three Y-connected series transformers are shown in Fig. 10, the only advantage in using three being that they will maintain more nearly a true ratio at light loads than will two. If transformer *T* is omitted the line shown connected to its upper terminal is connected to the bottom terminals of the other two.

as the one connecting to the left and middle, but the one on the right should have a lead brought out at the middle point of its secondary winding.

The accuracy of this connection and the reason for the equality of the readings on two wattmeters connected as in Fig. 11 may be
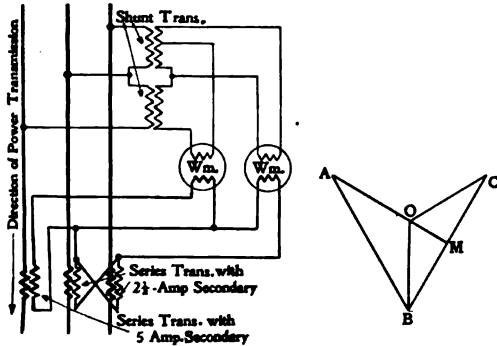
FIG. 11—SINGLE-PHASE WATTMETER CONNECTIONS AND VECTOR DIAGRAM OF CURRENTS AND VOLTAGES
Two wattmeters connected to a three-phase three-wire circuit so that a balanced load is equally divided between them, irrespective of power-factor. Two special series transformers are required.

shown by reference to the vector diagram. The phase relations of the currents in the left, middle, and right hand series transformers are indicated by OA, OB, and OC, respectively. The e.m.f.'s of the left and right hand shunt transformers are AB and BC. The e.m.f. on left hand wattmeter is the resultant of AB and $\frac{1}{2} BC$, which is represented by AM,

and equals $\sqrt{3/2}$ times AB. At 100 percent power-factor this is in phase with the current OA, which is the current in the left hand

wattmeter. This wattmeter therefore measures the power transmitted by the left hand line, on the assumption that the neutral point is at M, which is midway between the other two lines. The other wattmeter has the other two currents, OB and OC, reacting with the e.m.f. BC; but each of these currents has only one-half of its correct value, so that the effect is the same as OB and OC reacting with $\frac{1}{2} BC = BM = MC$. This wattmeter, therefore, measures the power trans-

FIG. 12 — POLYPHASE WATTMETER AND SINGLE-PHASE POWER-FACTOR METER ON A THREE-PHASE THREE-WIRE CIRCUIT

mitted by the middle and right hand lines on the same assumption as before, that the neutral point is at M. This assumption is permissible, for the power transmitted is the same, wherever the neutral point is, so that the two meters measure the total power transmitted, whether the load is balanced or unbalanced. That the power

measured will be equal in the two meters is shown from the fact that the left hand meter measures e.m.f. $\sqrt{3}/2$ times *AB* multiplied by current *OA* and the right hand meter measures e.m.f. *BC* multiplied by one-half the resultant of currents *OB* and *OC*. The two e.m.f.'s are equal, the three currents are equal, and the resultant of two of them is $\sqrt{3}$ times either one. The two wattmeters must therefore read the same with balanced loads.

A polyphase wattmeter and single-phase power-factor meter may be connected to the same transformers as shown in Fig. 12.
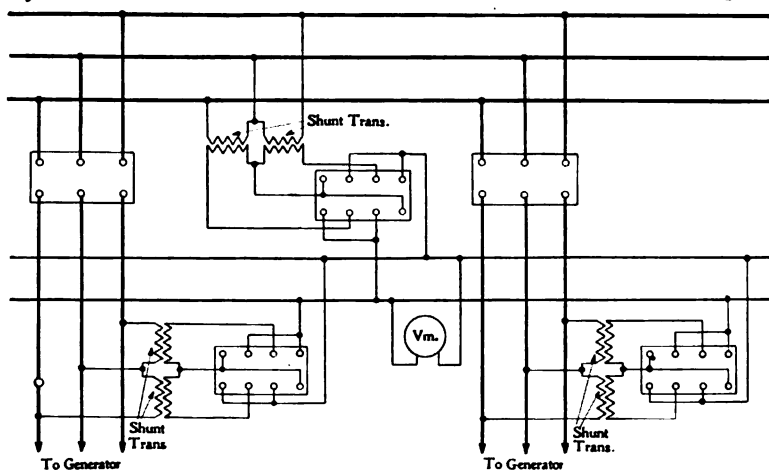
FIG. 13—CONNECTIONS FOR A SINGLE VOLTMETER USED WITH VOLTMETER
RECEPTACLES

The voltage across any phase of any number of three-phase three-wire circuits may be measured by means of an eight-point voltmeter receptacle on each circuit.

The wattmeter reads correctly with all kinds of loads. The power-factor meter reads correctly with balanced load and with a single-phase load on the *right* and *left* hand lines.*

VOLTMETERS AND AMMETERS

By means of three eight-point voltmeter receptacles, a single voltmeter may be connected so as to measure the e.m.f. between any two of the bus-bars or between any two of the lines leading to either of two generators. The connections are shown in Fig. 13. By increasing the number of receptacles, the number of different circuits to be measured may be increased indefinitely. A single four-point voltmeter plug is used, which makes connection between any two consecutive points in the upper row of any receptacle, and

*This use of a single-phase power-factor meter is discussed more fully in the JOURNAL for October, 1908, in the reference to Fig. 13, p. 605.

between the two corresponding points directly below these. For example, if the plug is in the four middle holes of the receptacle on one of the generator circuits it connects one voltmeter lead to the left, and the other to the right hand line of that circuit. If it is at the left hand end of the receptacle it connects the voltmeter to the left and middle lines.

Likewise, in Fig. 14, the current in any of the nine lines lettered A to I, may be measured on a single ammeter by the use of nine ammeter receptacles connected to four series transformers. The current from the upper transformer of the left hand circuit flows through the upper left hand receptacle A and unites with the current from the upper transformer on the right hand circuit, which has just passed through the upper right hand receptacle G. This combined current flows through the upper middle receptacle D, unites with the corresponding current from the lower row and then passes through the middle receptacle E of the middle row. After this it divides, the current from the left

FIG. 14—AMMETER USED WITH NINE AMMETER RECEPTACLES

With this combination it is possible to measure the current in each line of three three-phase circuits. With the plug inserted in a given receptacle, the meter measures the current in the line bearing the same letter.

hand transformers returning through the left hand receptacle B and that from the right hand through the right hand receptacle H. The current in line D being the resultant of currents in A and G, is measured when the ammeter is connected into the circuit by a plug in receptacle D. Similarly, the current in line B is the resultant of the currents in A and C, and is measured when the plug is in receptacle B. Also, the current in line E is the resultant of currents in B and H and is measured when the plug is in receptacle E, which carries the resultants of the currents in B and H. Each receptacle is lettered to correspond with the letter on the line whose current it measures.

An ammeter and voltmeter, connected to shunt and series transformers through a voltage compensator as shown in Fig. 15, indicate the current in one line of a three-phase circuit and the e.m.f.
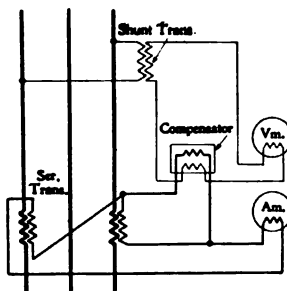
FIG. 15—AMMETER, VOLTMETER AND VOLTAGE COMPENSATOR ON A THREE-PHASE CIRCUIT

between this line and another one of the same circuit at a distant point, the compensator being set to make the right voltage correction for line drop. The current circuit of the compensator receives the current from the two series transformers, so that the voltage correction that it makes is proportional to and in phase with the drop in two lines. By using a voltmeter receptacle, the voltmeter connection may be shifted so as to measure either the distant e.m.f. or that at the transformer. An ammeter receptacle may be used in connection with the ammeter in order to make it possible to connect it to either of the series transformers.

A group of three ammeters and two overload relays, connected to Z-connected series transformers, is shown in Fig. 16. Each of the ammeters is in series with a single transformer, but each of the relays is on two transformers. If only a single ammeter is used it may be connected to three receptacles, each in place

FIG. 16—AMMETERS AND Z-CONNECTED RELAYS ON A THREE-PHASE THREE OR FOUR-WIRE CIRCUIT

of one of the ammeters shown; it may be inserted at *A*, measuring the current from the middle and right hand transformers, which is equivalent to the current in the left hand transformer on a three-wire circuit, or it may be connected in the circuit where one of the ammeters is located in the present diagram.

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*For complete description of the application and use of this device see article by Mr. William Nesbit on "Voltmeter Compensation for Drop in Alternating-Current Feeder Circuits," in the JOURNAL for January, 1908, Vol. V., p. 26.

EXPERIENCE ON THE ROAD

GORDON KRIBS

Erection Engineer, Canadian Westinghouse Co., Ltd.

I N reading the very interesting article by Mr. Olin on "A High Tension Rheostat," which appeared in a former issue, several experiences in this line were brought to mind.

TEST OF HIGH VOLTAGE GENERATOR AT CONSTANT POWER-FACTOR

A temperature test was to be made on a 250 kw, 25 cycle, three-phase, 2 200 volt, generator which was direct-connected to a water wheel and which was guaranteed not to exceed a certain temperature rise when run at full-load and 90 percent power-factor. The generator was loaded by means of a large motor driving an air compressor, a number of small motors running light and a water rheostat. The large motor being fully loaded had a high power-factor and by a proper combination of small motors together with the water rheostat, both the load and power-factor were adjusted for an eight hour run. The moving element of the water rheostat, in this case, consisted of a dry piece of wood approximately 14 inches square and two inches thick, in which were bored three holes so as to form an equilateral triangle ten inches to a side. Into these holes three two-inch iron pipes about 3½ feet long were fitted and leads were fastened to the ends of the pipes by means of bolts.

As the river at this point could not be used, a barrel was pressed into commission and the frame was suspended in it by means of a rope and pulley. The water had to be replenished constantly and care had to be taken to keep the pipes suspended in the centre of the barrel so as to avoid leakage of current to the hoops which would result in burning of the barrel.

WATER RHEOSTAT SUBSTITUTED FOR CONTROLLER

On another occasion an amusement park purchased a 30 hp, three-phase, 550 volt variable speed induction motor for use in driving a circle swing and for some unknown reason the controller did not accompany it. As the park company was losing money daily by the non-arrival of the control apparatus, it was finally decided to make use of a water rheostat. An ordinary oil barrel was obtained and after being thoroughly cleansed, was filled with water. The moveable element was again made by securely fitting into a dry maple disc 1½ inch pipes of the proper length, leads being run from

the motor slip rings to the pipes and the whole being suspended in the barrel by means of a window cord running over two pulleys. A counterweight sufficient to hold the moveable element in any position in which it was put, was hung on the other end of the rope. Salt was then added to the water to increase its conductivity until it was found that the motor could be started easily and gradually brought up to speed by lowering the frame in the water.

The rheostat was found to work with complete satisfaction, the speed of the swing being more completely under the control of the operator than if the regular apparatus had been used. In this case the radiation was sufficient to keep the temperature of the water within the proper limits even when running continuously.

ANOTHER EMERGENCY MOTOR STARTER

A mining company recently installed a 300 hp, 25 cycle, three-phase, 2 200 volt variable speed motor, the speed variation as in the case just described being obtained by inserting resistance in the circuit of the wound rotor. This machine was belted to a large air compressor which was to take the place of a steam driven outfit and on account of the scarcity of coal it was urgently needed. When all was ready to connect up it was found that some of the grids were broken and had to be sent back to the factory and the writer was sent out to see if it were not possible to operate the machine without them. The only thing which could be done under the circumstances was to rig up a water rheostat and this was done.

A rheostat similar to the previous one was made and it was fitted with a short-circuiting switch so that when the motor reached its running speed the rheostat could be cut out. Salt was added to the water so that with the pipes only partly submerged the motor could be started without any rush of current. Here the salt performed the double purpose of regulating the resistance and lowering the freezing point of the water. The water in the barrel got very hot if the rheostat was left in circuit for any length of time, but as it was used only in starting, this was not objectionable.

This type of rheostat is very useful to the man on the road and with a little ingenuity it can be applied in almost any case where a rheostat for three-phase current is desired. It is simple and inexpensive and can be easily and quickly made by even an inexperienced workman. This is a great advantage, as good workmen are often difficult to procure and the material used has to be obtained from a scrap pile.

A MYSTERIOUS MOTOR

There should be nothing mysterious about direct-current "trouble" work and yet strange things sometimes happen. The writer once visited a department store on a motor trouble case. The motor was a 110-volt belted machine and was used to drive a mattress cleaner or some such device. On removing the belt the motor revolved all right, but could be stopped by putting the hand on the pulley. If left to itself it ran at an excessive speed. Strangely enough, however, the stopping of the motor by hand did not blow the fuses, but the motor would not operate again after having been so stopped. No sparking or heating was apparent and the connections were correct. Here was plainly a set of conflicting facts and to add to the difficulty, while these facts were being considered, the motor started up of itself and ran up to about double speed, but was again stopped without difficulty and without blowing the fuses. Immediately after this it could not be started and a lamp put across the switch terminals indicated no voltage. In spite of the expert advice of the electrician of the plant it was evident that something was wrong with the source of power. Investigation showed that it was an Edison three-wire system with 220 volts across the outside mains and all fuses were apparently intact. On returning to the motor it was found that it could now be started. The starting switch was opened and a lamp, put across the terminals, indicated about 110 volts. This made the case more puzzling and apparently indicated trouble in the motor. However, as the writer's limited experience did not include motors that suddenly and mysteriously stopped running without blowing fuses, heating or sparking, such a conclusion had to be fought off.

Whether a line of reasoning could have been worked up on the data in hand cannot now be stated, for at this point a very irate floorwalker button-holed the electrician with a complaint in regard to an incandescent lamp in the next room to that in which the motor was located. This lamp had burned out several times, alternately burning very bright, burning very dark or not burning at all as the case might be, although there were several lights in the same room as the motor, which had burned calmly through all the trouble.

One rule of trouble hunting is to keep busy and the worse things become involved, the busier one should become. The one obvious thing left to do was to trace the circuits back to the street outlets or until the connections were plain. The electrician now re-

membered another three-wire fuse box and upon investigation, its middle fuse was found to be blown. The fuse was replaced by a much heavier one and the motor now ran to the satisfaction of everyone. The explanation of the erratic action of the motor is evident from the diagram in Fig. 1. The blowing of the neutral fuse put the motor and lamp in series and the stopping of the motor put 220 volts on the lamp and burned it out. The motor switch was then opened and the lamp replaced in order to remedy the trouble at this point. Whoever replaced the lamp evidently gave it up as a bad job, and matters were in this condition when the writer first started the motor by means of its starting box. The lamp first burned brightly, then fell to a dull red as the motor took all the voltage. The floorwalker now took a hand and, as we stopped the motor, was

FIG. I
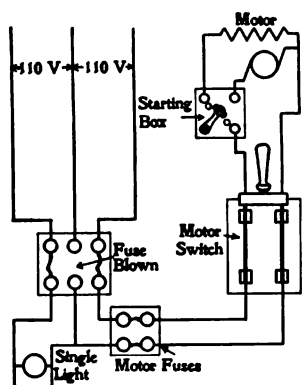
disgusted to see the lamp burn up very brightly, as a result of the double voltage, and then puff out. He removed the old lamp and put in a new one, thereby again starting the motor for us. While he thus puzzled us, we reciprocated by stopping the motor and burning out his light. He tried again with another lamp, but as we had opened the switch, his light circuit was open. He then went in search of the electrician, leaving his good lamp in and we put our test lamp across the switch, it being in series with their lamp and indicating 110 volts, i.e., dividing the 220 volts evenly.

What further combinations might have been made if the open fuse had not been discovered the reader can picture for himself, when it is stated that this happened in the forenoon when only one light was needed. On that particular circuit other lights were connected and on the motor side several lights were tapped in to supply a small workroom. It is evident that, as the motor had not been used for several days, this fuse may have been blown for some time and as the two circuits had about the same number of lamps, they would burn satisfactorily in series.

A NOVEL USE FOR OLD AUTO-STARTERS

R. H. FENKHAUSEN
Chief Electrician, Risdon Iron Works, San Francisco, Cal,

In a large western shipyard using alternating-current for both lighting and power, it is customary to supply lighting current to ships undergoing repairs by running 110 volt single-phase lines direct to the ship's switchboard. One morning, however, a ship came in, which was wired for 60 volts and, as the sockets were of the English "bayonet joint" type, it was impossible to change the lamps. The possibility of running a half voltage tap down from the power house transformers was considered, but the distance was too great and the time too short. It was, however, "up to us" to do something quick. Somtime previous three 15 hp two-phase 220 volt meters had been bought second hand and as the plant voltage was 440 volts two-phase, the motors were reconnected. As the starters for these motors were of the old air-break pattern, it was not thought advisable to get new coils, so new 440 volt oil-break starters had been purchased. The old starters were hunted up and they proved to be of 5-15 hp rating at 220 volts. At 110 volts the three starting taps gave 60, 80 and 90 volts approximately, they were then all connected for 60 volts and all three pairs of coils connected in parallel and taken down to the dock and connected in the circuit leading to ship. The copper loss was rather high and the regulation poor, due to the coils being designed for 220 volts, but on the whole they gave entire satisfaction, and were used until the job was completed.

About six months later a very large steamer came in. When connected to our lines the load proved to be too great for the feeders and the voltage dropped to 90 volts. The expense of running more copper was too great, so our bank of auto-starters was again brought forth, connected for 90 volts, installed aboard the ship, this time to boost the voltage instead of lowering it, and carried the load for three months with entire satisfaction to everyone.

THE JOURNAL QUESTION BOX

187—TRANSMISSION LINE CALCULA-
TIONS—Please give convenient
formula for determining the
size of wire for long distance
transmission lines taking into
account the effect of induct-
ance and capacity, distance of
transmission, frequency and
voltage of the generator, al-
lowable drop, total power
transmitted, and the distance
between the wires being
given?   T. E.

We know of no single formula
covering transmission line calcula-
tions. Simple methods for using tables
and diagrams are given in various
articles in the JOURNAL. In trans-
mission lines now in use the voltages
employed and the kw capacity and
distance over which power is trans-
mitted are such that the *capacity*
factor (electro-static) is practically
negligible and hence is not ordinarily
taken into account in transmission
line calculations. See the following
acticles in the JOURNAL: "How to
Calculate Regulation," by Mr. J. S.
Peck, Vol. II., p. 361, June, '05; "In-
duction in Transmission Circuits,"
by Mr. Chas. F. Scott, Vol. III., p. 81,
February, 1906; "Limiting Capacities
of Long Distance Transmission
Lines," by Mr. Clarence P. Fowler,
Vol. IV., p. 79, February, 1907;
"Drop in Alternating-Current Lines,"
by Mr. Ralph D. Mershon, Vol. IV.,
p. 137, March, 1907, and "Subsequent
Examples," p. 153; "Drop in Alter-
nating-Current Circuits," by Messrs.
Chas. F. Scott and Clarence P. Fow-
ler, Vol. IV., p. 227, April, 1907.
     C. P. F.

188—GROUNDED SECONDARY — In a
100-watt, 15 000-volt primary,
100-volt secondary voltage

meter transformer in which
the case and middle tap of the
secondary are grounded, are
the coils protected thereby
from lightning or sudden rises
in voltage? What is the ef-
fect of the grounded sec-
ondary in case of breakdown
on the primary coil?

In case of breakdown from the
high tension side to the low tension
side of the transformer, the fact
that the latter is grounded prevents
any abnormal rise of potential above
the rated secondary potential.
Grounding of the case prevents an
abnormal potential thereon resulting
from either induced voltage or
breakdown of the insulation. The
general phenomenon of primary and
secondary potential is discussed in
the article on "The Protection of
Electrical Circuits and Apparatus
from Lightning and Similar Dis-
turbances," by Mr. R. P. Jackson, in
the JOURNAL for February, 1908, Vol.
V., p. 85.   R. B. I.

189—EXTENDING METER LEADS—In
our power house there are
three ammeters connected to
a three-phase—four-wire cir-
cuit. We wish to move one
of these ammeters a distance
of 150 feet to the boiler room.
What size of wire should be
used and what error would be
introduced in the reading of a
wattmeter which is operated
from the same series trans-
former? The ammeters are
400 ampere capacity and the
maximum load is approxi-
mately 200 amperes per phase.
     R. F.

It is advisable to use as large a

size. wire as is available so as to
have as little resistance introduced
into the ammeter circuit as possible.
Induction in the leads may be ma-
terially reduced by twisting them
together. The effect of additional
resistance in the circuit from the
series transformer to the ammeter
on its calibration depends also on
the regulation characteristics of the
transformer. If it is necessary to
use extension leads of rather small
wire, it is advisable that this fact
should be given consideration and a
recalibration should be made in ord-
der to make allowance for the errors
introduced in the meter readings. P. M.

190—VECTOR DIAGRAMS FOR TRANS-
FORMER CALCULATIONS—Please
give references which treat, in
an elementary way, of the re-
sults of various transformer
combinations. I wish to be
able to predict accurately by
means of vector diagrams
what c.m.f.'s and phase differ-
ences are given by the various
combinations required in prac-
tice.   L. B. P.

For information regarding the ap-
plication of vector diagrams to alter-
nating-current problems, see article
on "Notation for Polyphase Cir-
cuits," by Mr. Chas. H. Porter, in the
JOURNAL for September, 1907, Vol.
IV., p. 497, also editorial, p. 484. See
also series of articles on "Applica-
tion of Alternating-Current Dia-
grams," by V. Karepetoff, in Vols. I.
and II. of the JOURNAL; the two in-
stallments referring particularly to
transformer applications are those
appearing in the June and August,
1904, issues, pp. 279 and 410, respect-
ively. See also "Vector Diagrams
Applied to Polyphase Connections"
in the series on "Meter and Relay
Connections" by Harold W. Brown,
in the JOURNAL for June, 1908. Re-
garding the example which you give,
see article on "Three-Phase—Two-
Phase Transformation," in the JOUR-
NAL for October, 1907, p. 598. E. C. S.

191—ADJUSTMENT OF SPARK COIL—
In a spark coil used to give
the jump spark for a 15-hp
engine, it is found that when
the current is strong enough
to give a satisfactory spark,

the contacts on the vibrator
wear away very rapidly. Is
this a difficulty liable to be in-
herent in spark coils, or is it
possible to adjust the vibrator
and battery voltage so as to
overcome the difficulty, and if
so, how should this be done?
                           W. O. M.

The only remedy for preventing
wear at the contacts is to prevent
sparking. If the contacts are ad-
justed to give the proper spark on
the secondary and sparking still oc-
curs at the primary contacts, the
only remedy is an adjustment of the
condenser connected across the con-
tacts. There should be no sparking
whatever when a suitable adjustment
of the condenser is obtained. It is
difficult to make any alteration in the
condenser on an ordinary jump
spark coil, as this requires opening
the case to get to the leads. For
trial, an additional condenser may
be connected across the contacts on
the outside. The wearing away may
be materially reduced by substituting
iridium for platinum at the contacts,
also by keeping the contact surfaces
clean, flat and with a strong pres-
sure between them.   A. B. R.

192—HEAT VALUES OF GASES—In an
article on "Some Points in the
Design of Large Gas Engines"
in the JOURNAL for May, 1908,
the statement is made that gas
engines are now operated on
various kinds of fuel gases
varying from 90 to 2 000 B.t.u.
per cu. ft. Is the latter value
quite correct? if so, what is
their performance when gas of
such high heat value is used?
What are the average heat
values of the various gases or-
dinarily used in gas engines?
                          J. G. O.

The value of 2 000 B.t.u. per cu. ft.
is correct for a gas known as "Pe-
troleum Distillate." This gas con-
tains all of the higher, hydro-carbon
(C H) elements whcih are so vola-
tile that they cannot be condensed
into commercial oils that will stay in
the liquid state at ordinary temper-
atures. Although having many im-
purities it may be used in gas en-
gines. The use of this otherwise

wasted by-product has been tried with success by the Atlantic Refining Company, of Philadelphia, for the operation of several gas engines of about 500 hp capacity. The approximate values of the various gases used in gas engines are as follows: Petroleum Distillate, or "Oil Gas," 1 800 to 2 000 B.t.u. per cu. ft.; Western Penn'a Natural Gas, 1 000 B.t.u.; Coal Gas, 666 B.t.u.; Water Gas, 292 B.t.u.; Producer Gas, 130 B.t.u., and Blast Furnace Gas, 90 B.t.u. per cu. ft.   F. J. H.

193—POWER-FACTOR BY WATTMETERS —On a balanced three-phase circuit how is the power-factor obtained with two integraitng wattmeters? Why is it that the above is an incorrect method on an unbalanced three-phase circuit?   A. E. S.

The power-factor is given by the ratio of the readings of two indicating wattmeters, as explained in No. 67 in the May issue. With two *integrating* wattmeters on a balanced three-phase circuit, the power-factor is given by the ratio of the readings of the two meters, the readings of course being taken for the same time interval. As the ratio of the two readings determines the power-factor it is evident that on an unbalanced three-phase system this method would not hold.   H. W. B.

194—CURRENT-SAVING DEVICE — We have been furnishing alternating current to a moving picture machine, giving them a flat rate. The customer has purchased an apparatus called an "electrocide," guaranteed to cut down light bills and save electric current, which is, as nearly as we can tell, a reactance coil. When a watt-meter is put on the service we find that it indicates only about 40 percent of the current that flows when an ordinary rheostat is used to regulate the current. What effect does the reactance coil of the electrocide have on our service? In other words, what allowance, if any, ought we to make them for saving current?   G. B.

Without having a diagram of connections of the device or of the mov-

ing picture machine, it is not obvious to us whether a reactance coil or an auto-transformer is employed to reduce the voltage to that required by the machine, and, thereby, to limit the current. In case an auto-transformer or step-down transformer is used the total amount of power is reduced in practically the same proportion as the indications of the wattmeter. If a reactance coil is used, the power is likewise reduced as indicated by the difference in wattmeter readings, but the wattmeter, however, does not indicate the effect which the choke coil has in reducing the power-factor of the circuit supplying power to this customer. In either case a reduction in the flat rate would be justified by the reduction in power; in case a transformer is used a reduction proportional to the power saved is reasonable, while in case a reactance coil is used, a reduction proportional to about one-half to two-thirds of the saving in power would seem reasonable although the total power consumed by this customer is probably not large, and therefore the effect which this device would have in reducing the power-factor of the generator circuit would possibly be so small as to be negligible. In this case a reduction in the flat rate proportional to the saving in power would then be reasonable. A statement of the effect of low power-factor on alternating-current generators is given in No. 142 in the JOURNAL for September.   C. R.

195—BLACKENING OF COMMUTATOR— Referring to Mr. B. C. Shipman's article on "Blackening of Commutator," in Vol. II. if the JOURNAL, p. 353, please explain why the blackening begins at a definite place on the commutator instead of blackening the whole commutator equally.   J. S. G.

Blackening of the commutator, appearing at a definite point as referred to, is probably due to some mechanical action which disturbs the brush contact at a particular point in each revolution of the armature, this resulting in a slight sparkling at the brush at that point. Electrically, trouble is as likely to start at one

place as another. The effect of sparking is to blacken the commutator, the action usually being slight at first, gradually increasing and spreading around the commutator if the cause is not removed. Some of the causes of sparking are: a badly laced belt, a bad tooth in a gear wheel, springing of the shaft of the engine with each stroke, loose bearings or wide variation in load during each revolution such as is encountered in the operation of reciprocating pumps, air compressors, etc.   W. A. D.

196—THREE AND TWO-PHASE CURRENT FROM T-CONNECTED TRANSFORMERS—With two transformers having their primaries connected three-phase T, is it possible to take simultaneously from the secondary both two-phase and three-phase current, the phases still remaining balanced? If this is possible, please explain, and give also, direction of current inside the transformers and tell what reduction there will be in the k.v.a. capacity of the transformers.   S. E. J.

Provided neither load has a ground or other common point both two-phase and three-phase current may be taken simultaneously from the secondaries of the two transformers connected in T. This connection is shown in Fig. 196 (a). The two-
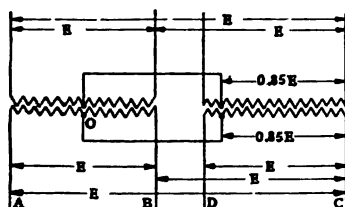
FIG. 196 (a)

phase current will be drawn from leads *AB* and *CD*, the three-phase from *ABC*. If both loads are equal to *EI*, the two-phase current will be $\frac{EI}{2E}=0.5I$ and the three-phase current $\frac{EI}{E\sqrt{3}}=0.58I$. The component and resultant currents are shown in Fig. 196 (b) ; $I''_{AO}=0.5I=$two-phase current in winding *OA*. $I'''_{OA}=0.58I=$

three-phase current in winding *OA*. $I_{OA}=$vector sum of I'' and $I'''=1.04I$ =total current winding *OA*. Likewise, $I_{OB}=1.04I=$total current in winding *OB*. $I''_{OC}=0.5I=$two-phase current in winding *DOC*=total cur-
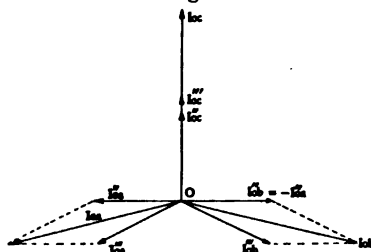
FIG. 196 (b)

rent in winding *DO*. $I'''_{OC}=0.58I=$three-phase current in winding *OC*. $I_{OC}=1.08I=$total current in *OC*.

On the primary side, the currents will be the same as if the whole secondary load were three-phase. Therefore, if the two-phase and three-phase loads are balanced, the whole system will be balanced. When two-phase and three-phase loads are equal the transformers will have 94 percent of their single-phase capacity for the same heating.   E. C. S.

197—SHAPE OF ARMATURE SLOT—Referring to No. 135 in the August issue, please explain what difference there would be in speed, efficiency of operation and heating in a direct-current armature with open and closed slots, the diameter of the armature being 16 inches and the air-gap 3/32 of an inch.   A. W. R.

There would be a difference in speed, efficiency and heating, so slight, however, as to be difficult to detect even a laboratory test. One effect due to the slot being partially closed would be to lower the speed, raise the efficiency and decrease the heating. The speed would be reduced because of the increase in cross-section of the tooth which would give a stronger field for the same excitation due to the decrease in the effective air-gap. The efficiency would be increased with the partially closed slot as the tooth section would be greater than with the

one having wedged grooves; hence the flux density and consequently the hysteresis loss would be decreased. Moreover, with open slots eddy currents are induced in the pole-faces both as the teeth enter and leave the magnetic field due to the variation of flux density introduced by the positions of the aperture of the slot and the tooth relative to the edges of the pole faces. With the closed type of slot the magnetic density is practically uniform as the tooth approaches and recedes from the edges of the pole faces. The motor with the lower iron loss will, of course, have the lower temperature.   A. R.

198—POLYPHASE INDUCTION REGULATOR—In our power station there is a discarded G. E. I. R. T. polyphase induction regulator, 2 200/220 volts, which is now being used to supply a 220-volt circuit. It formerly gave a wide variation in the voltage of the power line to which it was connected, whereas, in the present use it gives no variation in voltage whatever, when the rotor is turned from one extreme to the other. Please explain this.   F. T. S.

If the primary windings be connected in delta and the secondary windings in star, with no connection between the primary and secondary, the regulator will operate simply as a 2 200/220 volt step-down transformer and the secondary voltage will be independent of the moveable secondary.   E. E. L.

199—CARBORUNDUM - NEGATIVE RESISTANCE CO-EFFICIENT—I have observed that the resistance of a block of carbon carrying current decreases as the current increases; under similar conditions, would a stick of carborundum such as is sometimes used in series with a horn lightning arrester vary in a similar manner?   W. E. V. S.

Yes. The decrease in resistance in the carbon with increase of current is due to the rise in temperature, as carbon has a negative resistance co-efficient. Carborundum also has a negative resistance co-efficient; considerably greater than that of car-

bon, however, when pure carborundum is used. It may be adjusted to any desired value, within reasonable limits, by mixing the granulated carborundum with clay.   R. P. J.

200—POLYPHASE WATTMETER ON UNBALANCED LOAD—Two 2 200/220 transformers connected open delta supply three-phase induction motors. A connection is taken from the middle point of one of the transformers to supply a 110-volt, three-wire lighting load, the two outside wires of the three-wire circuit being connected across this same phase of the 220-volt circuit. With an unbalanced load on the three-wire lighting circuit, will the polyphase integrating wattmeter connected to the motor circuit between the lighting load and the transformers register correctly the total power supplied to the motors and lights?   F. C.

The current from one series transformer, *A*, reacts with the e.m.f. between the lines *A* and *B*, and the current from the other transformer, *C*, reacts with the e.m.f. between the lines *C* and *B*. If all the current flows through these three lines, the
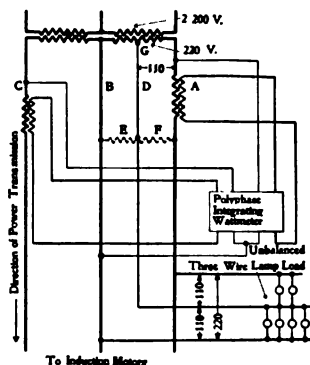
FIG. 200 (a)

resulting measurements are correct; but if, as in Fig. 200 (a), a current flows out through *D* and returns through *B*, an error is introduced, because this current does not affect the current in either series transformer and therefore indicates no

power. Similarly, if a current flows out through *A* and returns through *D*, the measurement of power due to this current would be twice as great as the actual power. It would be possible to connect an auto-transformer between the points *E* and *F* as shown by the dotted line in the diagram, and to connect the middle line of the 110-volt circuit to the middle of this auto-transformer instead of *G*. The wattmeter would then measure the total amount of power correctly.   H. W. B.

201—PARALLELING OF ALTERNATORS BY DIRECT CONNECTION—Having two three-phase alternators of the same voltage and frequency, and approximately the same output, it is desired to install them with their shafts end to end and couple them with a wide pulley, one-half being keyed to each shaft. How would you test them out to find where to cut the key seats so that the two machines would run in parallel?   C. C. B.

It is inferred that those machines are of practically the same design. Starting from the leads connecting the fields to the collector rings, determine by careful measurement the centers of the corresponding pole faces of the two machines. Likewise determine the center of the corresponding groups of windings of the two armatures. By bringing these two points directly opposite on each machine and then temporarily locking the couplings with the rotors thus placed, the position for parallel operation may be determined with fair precision. By clamping the couplings securely, the machines may be tested to check the relative positions before finally locating the key seats. This precaution would be especially advisable if the machines were not of exactly the same design. Another possible method, though probably less accurate, due to the static friction of the bearings, would be to excite the fields and one phase of the armature of each machine from a direct-current source, the rotating parts thus being brought into position magnetically.

202—HEAT RUN BY BUCKING FIELDS—Please explain the method of giving an alternator a heat run when only part of the field poles are effective while all are carrying full-load current. How is the correct number of effective poles determined?   E. B. H.

The number of effective spools to use may be calculated, after the saturation and synchronous impedance curves have been obtained from tests on the machine, by using the following formula: effective spools = $(b \times n) \div c$, where n = total number of spools on machine, b = field amperes required to give full-load armature amperes on short circuit, c = full-load field current. For three-phase machine, take 80 or 85 percent of the above; for single or two-phase machine, take 90 or 95 percent of the above. The values of c can easily be obtained from the curves by standard methods, for example, assume an alternator with 24 poles, full-load armature current, 600 amperes; from the synchronous impedance curve find the field amperes required to give 600 amperes when the armature is short-circuited, = say 14 amperes. From the saturation and synchronous impedance curves obtain the field current required at full-load amperes and normal voltage = 50 amperes; then the effective spools=$14 \times 24 \div 50$=6.7 85 percent of 6.7=5.7, or say six effective spools. In this case 9 spools should be bucked against the remaining 15.   J. J. L.

203—CHANGING A DIRECT-CURRENT MOTOR TO AN ALTERNATING-CURRENT GENERATOR—What changes are necessary to convert a direct-current motor into an alternating-current generator? It is desired to use the generator for testing armatures   C. B. F.

To obtain a single-phase generator it would simply be necessary to provide two slip rings connected to points on the armature 180 electrical degrees apart. At what point mechanical connection would be made for this purpose cannot be stated without information regarding the details of design of the particular

machine in question, such as the form of armature winding (*i. e.,* whether series or multiple-wound) ; the number of armature slots; the number of coils per slot; the number of commutator segments, and the number of poles. To obtain a three-phase alternating-current generator, three slip rings and three armature taps 120 electrical degrees apart would be required. If the motor be a multipolar machine with multiple-wound armature and its full capacity be required, the slip rings would have to be connected to corresponding points in the multiple circuits. It should be noted that the frequency obtained would be dependent upon the number of poles and the speed of the machine. More definite directions than the foregoing would require complete information regarding details of design of the machine and the characteristics of the generator which it is desired to obtain. F. D. N.

204—LOADING TRANSFORMERS FOR TEMPERATURE TEST—In loading two similar transformers as shown in the diagram of connections Fig. 204 (a), the magnetizing and loading current being taken from one phase of a three-phase generator, the ammeters show a larger current flowing in *A* than in *B*. Reversing the polarity of either magnetizing or loading circuit gives reverse conditions in *A* and *B*. When the magnetizing or loading currents are taken from the two phases of a two-phase generator, the same is found to be true, though, in this case, there is only a slight difference in the values of the two currents. Can the circuits in these two cases be represented by vectors? How does the test on these transformers compare with the true load conditions? Large 7 200 alternation transformers are often used, while on temperature test, excited at 7 200 alternations and loaded at 3 000 alternations. Can a diagram be constructed to show the components of the two currents indicated by the two ammeters? Such a diagram for this case would also be appreciated. B. E. S.

When running transformers on temperature test by the opposition method, the impedance of the loading circuit is the impedance of the transformers under test. Hence the power-factor=(copper loss by wattmeter)÷(impedance volts × current). The power-factor of the magnetizing current is of course=(true watts lost in iron)÷(apparent watts in iron). In the loading circuit the two transformers are in series; in the magnetizing circuit, they are bucking; hence the resultant current in one is the sum of loading and magnetizing current, in the other it is the difference, the addition or subtraction being determined by the relative polarity of the impressed e.m.f.'s. In large transformers the power-factors of the two circuits are approximately equal; therefore, when
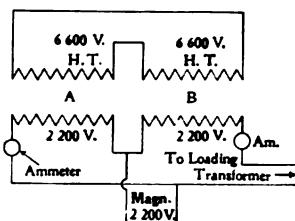
FIG. 204 (a)

both loading and magnetizing currents are taken from one phase— either of a single or polyphase machine—they are nearly in phase and add or subtract almost numerically. When the two currents are taken from separate phases of a two-phase generator, the magnetizing current is nearly 90 degrees from the loading current so that when they are added or subtracted, the power-factor has much less effect than in the first case. The conditions existing when the magnetization and load currents are taken from two phases 90 degrees apart approach very closely the conditions of full non-inductive load, so that this method should be used whenever possible. Single vector diagrams cannot be made to show conditions in currents of different frequencies. The vector diagram representing the relations of currents and e.m.f.'s with both circuits connected to sources of power of the same frequency are simple and are readily constructed from the foregoing. E. C. S.

Motor Applications

Too much importance cannot be attached to the value of an exact knowledge of all the conditions to be fulfilled when an application of the electric motor is under consideration. Some methods which may be used to obtain this information are outlined in the paper on "Industrial Engineering," by Mr. H. W. Peck, in this issue of the JOURNAL. The result of the application of one of these methods is strikingly illustrated, and curiously enough this method is the one which would probabl‹ be selected as the least practical by a majority of those ·vho delight to call themselves practical. Undoubtedly the larger motors operating the barrel hooping machines were doing the work in a thoroughly satisfactory manner, but it remained for a man who is not satisfied unless he has "figured it out" to demonstrate that a much smaller motor, in conjunction with a fly-wheel, would be even more satisfactory from an economic standpoint. A properly applied fly-wheel is of great assistance in certain classes of work in which the demand on the motor is of a fluctuating nature. Much valuable information on this subject was given by Mr. Brent Wiley in a paper on "Characteristics of Motors for Large Shears," published in the January, 1909, issue of the Proceedings of the American Institute of Electrical Engineers.

The collection of "objections" to the use of the electric motor, given by Mr. Peck, is interesting as illustrating the blindness of those who will not see the things which are obviously before them, but who are willing to devote any amount of time and energy to the futile task of trying to do things as they have always been done, while, at the same time, they are endeavoring to keep from being left behind in the race in which success is achieved by those who are willing to go into conditions thoroughly and change their ways of doing things in accordance with advances which come in the natural course of progression. The paper is evidently the result of analyses of a large number of individual applications, and is worthy of careful reading by all who are interested in motor applications.

A perfect machine may be driven by any motor possessing the

necessary characteristics, but the combination will not give the maximum return on the investment unless both the characteristics of the motor and the conditions of installation and operation are correct. It is only by the proper appreciation of all the features mentioned that thoroughly satisfactory applications may be accomplished. It is to be hoped that in a future article Mr. Peck will furnish us with some of the details of the work upon which his paper is founded.

J. H. KLINCK

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The International Edition

It is now a little over a year since the International Edition of the JOURNAL was started. The results in the way of better service and increased interest in the JOURNAL abroad have amply justified this step. The difficulties due to injury to the magazines in transit from Pittsburg to foreign subscribers and the delays due to long-distance correspondence have been eliminated. All articles in the American Edition also appear in the International Edition, among which have been numerous contributions from prominent foreign engineers. In addition a supplement is issued with the International Edition containing items of especial interest to its readers. An active interest is being taken in the JOURNAL abroad, in many cases new subscribers have been so favorably impressed that they have ordered bound volumes of the JOURNAL for previous years. The following item is from a recent supplement to the International Edition:—

THE NEED THE JOURNAL SUPPLIES

It happens occasionally that after a man has been struggling for a long time to understand some problem, he picks up an article which deals with the question in so simple and logical a way that he wonders why he should previously have had such difficulty in understanding it. He puts down the article with a feeling of admiration for its author, and with that satisfaction which comes only with the sense of having added to his store of knowledge. Engineers who inspire us with feelings of this kind are those who understand their subjects, who think straight and who have mastered the art of clear expression. One of the best writers of this type is Mr. B. G. Lamme, chief engineer of the American Westinghouse Company. His writings are free from mathematics, and he handles the most complicated problems in such a manner that they are readily understood by anyone who has even

an elementary knowledge of the subject. Some of his recent con-
tributions are masterpieces of engineering English. Mr. Chas. F.
Scott is another splendid writer of the same type who has done
wonderful work in clearing away the mathematically shrouded mys-
teries regarding alternating-current.

Following the lead of these men, other contributors to the
JOURNAL have kept their writings remarkably free from mathemat-
ics, and have aimed to present their problems in such form as to
enable the practical man to obtain a clear idea of the subject under
discussion. Articles found in the JOURNAL are not of an abstruse
mathematical nature, but rather of the practical kind which are most
likely to be of assistance to the every-day engineer. The great pop-
ularity of the JOURNAL is due almost entirely to the class of arti-
cles which it contains, and it has become not only a publication of
monthly interest, but a reference book of great value. A topical
index is issued each year, and by its aid it is possible to turn quickly
to any article on any subject which has appeared in the JOURNAL
since it was started. It is surprising to find what a rich mine of
information a little prospecting in the Topical Index reveals.

The Selection of Officers for American Institute of Electrical Engineers
Our national electrical society is about to make its
annual choice of officers, some for a term of one
year and others for two or three years. They will
direct the professional interests of the Institute
now enrolling nearly eight thousand, including its
students, and maintaining about fifty sections and
branches, and they will direct an annual expendi-
ture of about $80 000. This calls for a high
grade of ability. The men selected should he broad guage and
progressive, interested and earnest, able and efficient. They should
be chosen not that an honor may be conferred but that a service
may be rendered. Few who have not served on the Board appre-
ciate how large the affairs of the Institute have become and how
much work there is for the Board to do. While wide territorial
representation is desirable from some standpoints, it is essential that
there be but few who are too far away to attend Board meetings
and serve on committees. Relatively few of the present officers re-
side in New York City; only two of the eight new men elected last
year live in that city, but nearly all are close enough to attend and
usually do attend the meetings.

The present method of conducting the primary or nomination

ballot is haphazard and in some respects almost ludicrous. Rarely does one name receive ballots from more than, say, five percent of the membership and sometimes preference on the list depends upon differences of a few votes when no one has been proposed by two percent of the members. Last year there were 77 different names on the nomination ballots for president, 258 on those for vice presidents, and 524 on those for directors, and a very considerable proportion of these names occurred but once. Such scattering and so little definite concentration indicates the lack of means of presenting a few names before the membership at large. The circular letter, whether signed or anonymous, and announcements in the technical press are in danger of becoming undignified and are sometimes subject to abuse. Yet there is no other present method of securing concerted action. Should not the Institute itself provide a means of presenting preliminary nominations. If it were known for instance that the Proceedings—or possibly a special announcement— were to be the accepted channel by which names could be placed in nomination when endorsed by say ten members, it would render individual letters and controversy in the technical press unnecessary and would be serviceable to the average member in presenting lists from which to make selection. Concise statements regarding the qualifications of the candidates presented would be appropriate. The Institute is this year publishing in the Proceedings the proposal list of last year and the names of those who have held office in recent years. This is useful, but obviously does not meet the needs above indicated.

The Institute has increased in membership four-fold in eight years, and its activities have in many ways kept pace with its membership. There are larger possibilities in the future, which need as leaders the ablest men in the profession.   CHAS. F. SCOTT

ITALIAN POWER PLANTS
AS SEEN THROUGH AMERICAN EYES
"Die Kraftwerke Brusio"
S. Q. HAYES

E VERY engineer who has travelled through the northern part of Italy has noticed the large number of power plants around the city of Milan, and many descriptions have appeared from time to time in the technical press regarding these plants. Each engineer, when visiting these plants pays particular attention to the features that are of the greatest personal interest to him and that differ most from the practice with which he is accustomed. The writer, during a recent trip to Italy, had

FIG. I—GENERATOR ROOM, CAMPOCOLOGNO STATION

the opportunity of visiting several of the plants of the "Societa Lombarda per Distribuzione di Energia Electrica," and secured some excellent illustrations of the stations visited. He also managed to take a few kodak pictures in the Castellanza station, and these cuts and photographs have been used to illustrate this article and to point out the features that were particularly noticeable, from the writer's point of view.

The Societa Lombarda has various generating and transforming stations in the northern part of Italy where it supplies a large amount of power to factories. The main hydro-electric generating stations are at Turbigo, Vizzola and Brusio, the latter being the newest and largest station, and comprising a hydraulic

generating station at Campocologno, on the Swiss side of the boundary line and a step-up transforming station at Piattamala, on the Italian side. These stations are connected together by means of a tunnel approximately 1 600 feet long, containing two 7 000 volt feeders each of approximately 18 000 k. v. a. capacity, these two stations together being known as the Brusio plant.

While the hydraulic features of this plant have been very carefully worked out and are very interesting to hydraulic engineers, attention will be given in this article simply to the electrical features that particularly appealed to the writer as departing materially from American practice.

FIG. 2—GENERATOR CONTROL CABINET
Front View.

The interior of the generator room of the Campocologno station is shown in Fig. 1, this being approximately 46 feet wide by 320 feet long, and adjoins a bus-bar room which has approximately the same length as the generator room and a width of about 11 feet. This station contains twelve hydro-electric turbine units each of 3 000 k. v. a. capacity, comprising Escher-Wyss horizontal turbines of the Pelton type operating at 375 r. p. m., direct-connected to Alioth generators of 50 cycles, 6 300 to 7 700 volts, having 25 percent overload capacity for two hours. There are also four exciter turbine sets with Piccard-Pictet turbines, running at 430 r. p. m. and driving 150 kw, 115 volt exciters. The turbines and generators are connected by means of elastic couplings.

The connections at this plant are so made that exciters No. 1 and No. 2 can be connected to either or both of the two sets of exciter busses, while exciters No. 3 and No. 4 can only be con-

nected to the upper set, which set is provided with sectionalizing switches located between exciters Nos. 2 and 3. The generator field circuits for generators Nos. 2 and 3 are provided with knife switches in addition to the field switches, so that they can be excited from either set by field bus-bars, while generators Nos. 4 to 12, inclusive, can only be excited from the upper field bus. Generators Nos. 1, 2 and 3 are provided with two sets of disconnecting switches for connecting to the main or auxiliary busbars, while generators Nos. 4 to 12 only connect to the main bus. This main bus is divided in the middle, between generators Nos. 6 and 7 and each of these two sections feed through a non-automatic oil switch to the Piattamala transformer house.
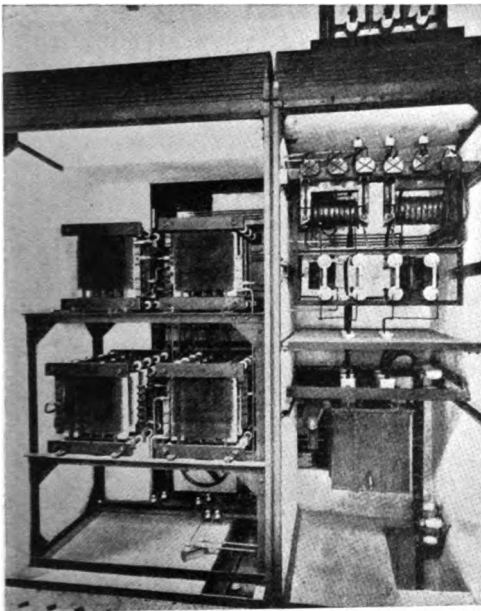
FIG. 3—GENERATOR CONTROL CABINET
Rear View.

GENERATORS

The 3 000 k. v. a. generators are revolving field machines with 16 poles and bolted-on pole caps. These poles are slightly bevelled and their overhanging tips are used to hold on the field coils. The stationary armature is provided with three slots per phase per pole, these slots being practically closed, and the conductors threaded through. These generators operate at a speed of 375 r. p. m., giving a frequency of 50 cycles per second and a normal voltage of 7 000 volts, and have a guaranteed full-load efficiency of 96 percent at 100 percent power-factor, and a guaranteed efficiency of 94.5 percent at 70 percent power-factor. The corresponding efficiencies at 25 percent overload are 96.5 percent and 95 percent respectively. The regulation at 100 percent power-factor is seven percent and the regulation at 70 percent

power-factor and 7 700 volts is 20 percent. The temperature rise is 45 degrees C. for a 24-hour full-load run.

CONTROL AND MEASURING APPARATUS

Opposite each generator is one of the generator control cabinets, shown in Fig. 2, front view, and Fig. 3, rear view. These cabinets are set in the station wall with the instruments and controlling devices in the generator room, while the switching devices, series and shunt transformers are in a closed cabinet projecting into the bus-bar room, as shown in Fig. 5. As may be seen in Fig. 2, each generator is provided with three ammeters operated from series transformers, which also supply current to the three single-phase overload relays mounted on the lower part of the central panel. There are also three voltmeters, one connected through a shunt transformer to the high tension bus-bars, and a second connected to the generator, and the third being used for synchronizing and connected in multiple with the two

FIG. 4—EXCITER SWITCHBOARD—CAMPOCOLOGNO STATION

synchronizing lamps shown on the panel. The remaining meter is the field ammeter. The operating handle on the left panel is used in connection with the field discharge switch, this switch being mounted inside the cabinet. The tripping solenoid of this field discharge switch is operated by means of the overload relay in the generator circuit at the same time as the tripping coil of the oil circuit breaker. With this arrangement the overload of any phase of the generator will trip out both the oil circuit breaker in the armature circuit and the switch in the field circuit. The large hand wheel on the central panel is used for

the operation of the oil circuit breaker, while the smaller hand wheel on the right hand panel is used for the field rheostat.

As indicated in Fig. 3, the leads from the generator come up through the floor, pass into the oil circuit breakers and then up

through series transformers and out through the top of the cabinet where disconnecting switches are provided for cutting off the cabinet from the bus-bars on the ceiling. One thing particularly striking in connection with this generator pedestal is the small size of the automatic oil circuit breaker used on a circuit connected directly to the bus-bars

FIG. 5—BUS-BAR ROOM—CAMPOCOLOGNO STATION

fed from 36 000 k. v. a. in generator capacity. In American practice, this type of circuit breaker would hardly be used in a station of much more than 4 000 or 5 000 k. v. a. capacity, but, apparently, little or no trouble is experienced with this type of circuit breaker in this plant.

Fig. 3 also shows the type of porcelain fuses used with the shunt transformers, as well as the grid type resistances used for field rheostats, and the diverter resistances used for the field discharge circuit. Under normal conditions, the backs of these cabinets is completely en-

FIG. 6—BUS-BAR ROOM—PIATTAMALA STATION

closed by means of iron doors that can be rolled up to permit access to the interior. In some stations an interlock is provided so that these doors cannot be opened unless the oil circuit breaker has been tripped and the disconnecting switches pulled out.

Fig. 4 shows the switchboard for the four exciters. This switchboard is of cabinet construction mounted against the station wall and erected on a low platform. Each exciter panel is provided with an ammeter, a voltmeter, a three-pole main switch, an automatic circuit breaker and a field rheostat. Double face alternating-current voltmeters are mounted on brackets at each end of the switchboard cabinet with a clock above the center of the cabinet. Placed in front of the switchboard on a small pedestal is an ammeter with ammeter switch arranged for connecting this meter in any generator circuit, a voltmeter with switch for connecting to any phase of either bus and two ammeters, one for each of the 7 000 volt outgoing lines which run to the transformer station. There is also a large hand wheel which can be used for operating one or more of the exciter rheostats at the same time by throwing suitable clutches. This arrangement permits the simultaneous adjusting of the rheostats of the various exciters operating in multiple.

FIG. 7—INCOMING FEEDER SWITCHBOARD—
PIATTAMALA STATION

BUS-BARS

Fig. 5 shows the bus-bar room in the generator station, and clearly indicates the manner in which the generator switching cabinets project into this room. The main 7 000 volt bus-bars are mounted on corrugated porcelain pillars supported on iron framework, and are not separated by any barriers or other enclosed structure. This is a decided departure from American

practice for a station of this capacity and voltage, as it is the almost universal custom to place bus-bars in masonry compartments in plants of more than 5 000 or 6 000 kw capicity at voltages in the neighborhood of 7 000 volts. It should be stated, however, that most of the Italian stations also place the bus-bars in compartments for stations of this capacity. These 7 000 volt bus-bars are sectioned in the middle by means of knife switches, and each section feeds through a non-automatic oil cir-
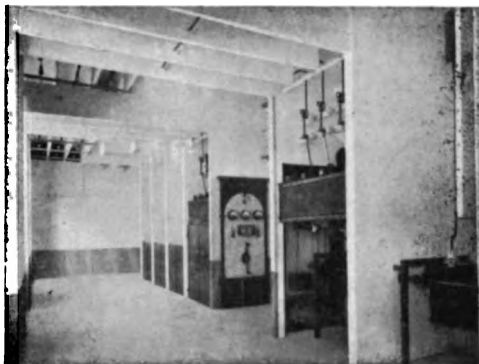
FIG. 8—TRANSFORMER CONTROL PANEL—PIATTA-MALA STATION

circuit breaker to the leads connecting the Campocologno and Piattamala stations. These connecting feeders, as mentioned previously, are run through a tunnel approximately 8 feet wide by 9½ feet high, and are mounted on petticoat insulators and separated by heavy concrete barriers built into the wall of the tunnel. The feeder leads after emerging from the tunnel are connected through knife switches to the bus-bars shown in Fig. 6. Each of the two incoming feeders supplies current to one set of bus-bars, which bars can be connected together at the center by means of knife switches. It seems rather odd that the bus-bars in the generating station should be entirely open, while the bus-bars in the transforming station are carefully enclosed between concrete barriers.
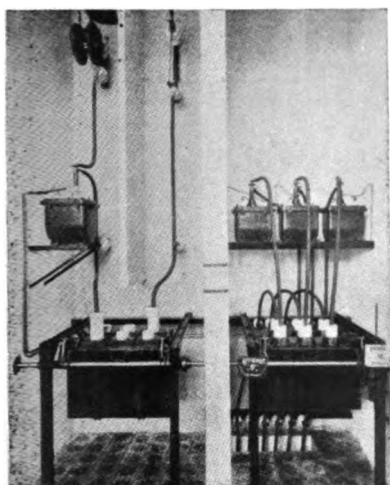
FIG. 9—OIL SWITCHES—CASTELLANZA STATION

In addition to the bus-bars in each of the three-phases, an auxiliary bus-bar connected to the neutral point of the low ten-

sion winding of the transformers is shown on the top-most row and
this bus-bar is connected to ground through a horn gap.

In this Piattamala transforming station, there are twenty-
four 1 250 k. v. a. oil-insulated, water-cooled single-phase trans-
formers of Alioth make. These transformers are connected in
groups of three for stepping up the voltage from approximately
7 000 volts to approximately 50 000 volts. These transformers
are star-connected on both the high and low-tension sides, and
the neutral points on both high and low tension stars are
grounded through horn-gaps.

Each of the 7 000 volt incoming feeder circuits is provided
with an instrument panel of the type shown in Fig. 7. On this
panel there are two polyphase graphic recording wattmeters
connected to independent series and shunt transformers, and
used as a check on each other. There are also three alternating-
current ammeters, and a voltmeter with voltmeter switch so con-
nected as to read the voltage across any of the three phases.

Fig. 8 shows the transformer control panel and the general
arrangement of the transformer switching devices in the Piatta-
mala station. Each group of transformers is provided with a
cabinet panel of the type indicated, containing three ammeters,
operated from series transformers in the low tension circuit, two
single-phase relays and one operating handle that closes the
three single-pole oil switches in the high tension circuit, and the
one three-pole switch in the low tension circuit. These switches
are operated from a single shaft which passes through the vari-
ous compartments and is actuated by the long double arm shown
near the bottom of the transformer panels. The overload relays,
operated from series transformers in the low tension circuit, trip
out both the low and high tension oil switches.

The type of oil switches used for the low and the high ten-
sion circuits is shown in Fig. 9, although this is a photograph
taken in the Castellanza step-down transforming station. The
switch on the left is one pole of the high tension circuit breaker,
which has three double breaks per pole. The three poles of the
high tension circuit breaker as well as the three-pole breaker are
operated by the shaft in the manner indicated. This illustration
also shows the oil-immersed, high-tension series transformer, the
spiral choke coils and the type of the high tension disconnecting

switch mounted on corrugated porcelain insulators used in these installations. The switch on the right is a three-pole switch in the low tension circuit, and all three poles are placed in the same compartment. Oil-immersed series transformers are also used for the low tension circuit as well as for the high tension circuit. One thing which was particularly noticeable in connection with the switch installation was the excellent character of the concrete masonry work used for barriers, shelves, etc.

Fig. 10 shows a group of three 1 250 k. v. a. single-phase oil-insulated water-cooled transformers, each transformer being placed in a separate compartment and located on slide rails in such a manner that it can readily be slid out and placed on a truck running on rails in front of the transformer compartments. One thing particularly striking in connection with these transformers is the rather peculiar shape of the tank, the upper portion containing the coils for the circulation of the cooling water being considerably larger than the lower, and instead of following the American practice of making the entire tank of the same size, viz.,

FIG. 10—TRANSFORMER GROUP—PIATTAMALA STATION

the size required for the cooling coils, these transformers have had the lower half of the tank made of considerably smaller dimensions. The reason for this peculiar design is the fact that the price of the transformer oil is very high, ranging from 3.5 to 5 cents per pound, so that it is of the utmost importance to reduce the amount of oil to a minimum. Fig. 11 shows one of these 1 250 k. v. a. single-phase oil-insulated transformers removed from its case and with the cooling coil taken off. These transformers, like nearly all those of continental manufacture, are of the core type, with concentric high tension and low tension windings.

Fig. 12 shows one of the 1 250 k. v. a. 42 000/11 000 volt air-cooled transformers installed in the Lomazzo substation. As may be noted, these transformers are not supplied with any case, but are located over the air blast chamber and are provided with dampers placed in the concrete foundations. Roller iron doors close the transformer compartments in the front and compel the air entering at the bottom to pass out through the top of the compartment, thus affording a maximum amount of cooling. These air blast transformers of Alioth make are particularly interesting, as American practice limits the field of air blast transformers to 33 000 volts. They have a guaranteed full-load efficiency of 97 percent; one-half load efficiency, 96.5 percent; regulation at unity power-factor full load, one percent; regulation at 80 percent power-factor full load three percent. Temperature rise 45 degrees C. over the temperature of the air. Insulation test 65 000 volts for ten minutes between iron and windings. Overload capacity, 25 percent for two hours, with a temperature rise of 60 degrees

FIG. 11—1 250 K.V.A. OIL-INSULATED WATER-COOLED 50 000 VOLT TRANSFORMER

C. These guaranteed efficiencies compare well with the guaranteed efficiencies of the corresponding 1 250 k. v. a. oil-insulated water-cooled transformers, which have a full-load efficiency of 97.5 percent, one-half load efficiency of 96.5 percent, regulation at 100 percent power-factor one percent, regulation at 80 percent power-factor 2.2 percent at full load. Temperature rise 45 degrees C. above the temperature of the incoming water when consuming 7.5 gallons of water per minute, having a maximum temperature of 15 degrees C. These water-cooled transformers have an overload guarantee of 25 percent for six hours, with a temperature rise of 60 degrees C. above the temperature of the water when

FIG. 12 — 1 250 K.V.A., 42 000 VOLT AIR-BLAST TRANSFORMER

consuming 15 gallons per minute, or the same temperature rise with a 25 percent overload for two hours when consuming 7.5 gallons

per minute. The insulation test of these oil-insulated water-cooled transformers is 65 000 volts for ten minutes between windings and iron.

LIGHTNING PROTECTION

For the static protection of the 50 000 volt line at the Piatta-mala transforming station and the corresponding incoming lines of the other stations, various types of lightning arrester equip-ment are in use. Each line is provided with a choke coil comprising two flat spiral coils mounted side by side on a pair of corrugated porce-lain insulators. These coils are connected in multiple. Several types of lightning ar-resters are installed, one consisting of horn gaps in series with non-arcing cylinders mounted in groups on bases supported on corrugated porce-lain pillars Discon-necting switches are provided for cutting off the horn gaps from the line, and combination resist-ances, and reactances are connected between the non-arcing cylinders and the ground.

FIG. 13—WATER JET LIGHTNING DISCHARGER

A second type of arrester comprises horn gaps in series with water resistances, the horn gaps being provided with knife switches for cutting off from the line. Probably the most inter-esting type of lightning arrester, from an American point of view, is that shown in Fig. 13. This arrester, or rather discharger, consists essentially of metal plates with arrangements for squirt-ing jets of water against their under sides. The ascending jets

and the descending spray form high resistance paths for the currents to ground. These water jet dischargers are connected in circuit only at the time of a lightning storm and ammeters are provided to indicate the amount of current being consumed. If this is excessive, the flow of water is adjusted to suit. Placed above the ammeters are knife type switches mounted on corrugated porcelain pillars for cutting off the lines from this water jet discharger. As may be noted, the ammeters are supported on high tension insulators and are connected directly in the high tension circuit.

TRANSMISSION LINES

The high tension transmission lines are carried on lattic work poles of the type shown in Fig. 14, which clearly shows the elaborate precautions taken where a high tension transmission line crosses a public road and the complete cage that is placed around the telegraph and telephone lines where crossed by the high tension lines. The transmission line towers carry four three-phase circuits arranged in the form of equilateral triangles, two on each side of the poles. The telephone line follows the usual Italian practice of placing insulators on each side of the vertical pole instead of the American practice of supplying cross arms, containing a large number of insulators. At Castellanza there is one high tension incoming line supplying power through disconnecting switches and oil circuit breakers, to banks of step-down transformers, each three 1 250 k. v. a. units being arranged similarly to the step-up transformers at Piattamala.

FIG. 14—TRANSMISSION LINE CROSSING HIGHWAY AND TELEGRAPH LINES

STEAM POWER PLANTS

In addition to the transformer plant, there is a steam plant

of a total capacity of 30 000 hp which acts as a reserve for the
Brusio station and for the stations at Turbigo and Vizzola. The
steam station comprises steam engines as well as steam turbines,
the latter being 5 000 and 7 500 hp capacity, and the former of
2 500 hp capacity. Fig. 15 shows one of the 7 500 hp turbo-gener-
ators of Brown-Boveri construction. The turbo-generator is of
the enclosed type, drawing cold air from the basement and dis-
charging the heated air at the top of the turbine. The cover of
the turbine is mounted with a pin and socket joint to facilitate
dismounting and is split in two parts in the manner indicated.

Each of the turbo-generators is controlled by means of the
pedestal shown in Fig. 15. This pedestal is provided with a
cast iron top, in the face of which are mounted flush type round
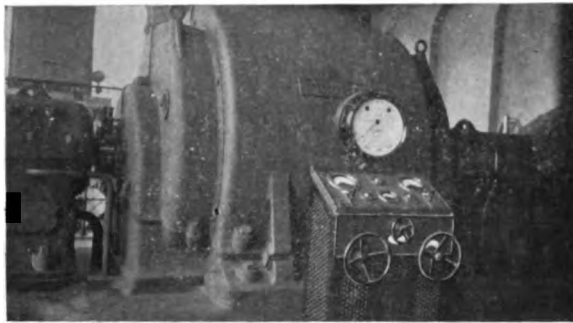
FIG. 15—BROWN-BOVERI TURBO-GENERATOR AND CONTROL
PEDESTAL

pattern instruments, synchronizing lamps, and similar devices.
Back of the pedestal is placed a combination instrument com-
prising a polyphase indicating wattmeter reading up to 8 000
kw, a voltmeter and an ammeter. The oil circuit breaker for
this generator is operated by means of a hand wheel and sprocket
mechanism while the rheostat is controlled by a similar hand
wheel and sprocket mechanism. The front, sides and back of
this central pedestal are of perforated sheet iron forming a cheap,
and apparently satisfactory, construction.

The feeder switchboard shown in Fig. 16 controls the vari-
ous circuits from the Turbigo, Vizzola and Brusio stations, as
well as the outgoing distributing feeders to Manfi, Cantoni,
Legnano, etc. The feeder panels are mounted on a rather elab-
orate iron framework, each panel standing independently with

considerable space between adjacent panels. These panels are provided with indicating instruments, graphic recording watt-meters, etc.

Back of the switchboard was located the rack containing the lightning arrester equipment, indicated in Fig. 17. These arresters are used in the 11 000 volt circuits, and comprise horn gap arresters with non - arcing cylinders, helical choke coils, etc. At the other end of the station is installed the present switch-board, containing an even

FIG. 16—FEEDER SWITCHBOARD—CASTELLANZA STATION

more elaborate set of protective devices.

The oil circuit breakers for the control of the various feeder and generator circuits in the steam station are of Brown-Boveri and Magrini manufacture, and from the appearance of the plant, some of these breakers, were very apt to spill oil whenever they o p e n e d under load. The general appearance of all of the plants on this system indicated that a great deal of attention had been paid to the details of construction.

FIG. 17 — 11 000 VOLT LIGHTNING ARRESTERS— CASTELLANZA STATION

There were many other points in connection with these various stations worthy of careful study, but those mentioned in this article were the ones that particularly caught the writer's attention.

INDUSTRIAL ENGINEERING

THE APPLICATION OF ELECTRIC MOTORS

H. W. PECK,

Electrical Engineer, Rochester Railway & Light Company

ROCHESTER has long been an industrial center, especially of those industries requiring mechanical power for the manufacture of their products. In these days this requirement includes practically every known manufacturing industry, but such was not the case fifty years ago, when human skill, acquired by long experience, was the chief consideration in most manufactures. In the early days the value of the water power of the Genesee river was appreciated and gave a natural start to the power industries. Water rights were secured, races were constructed, and mills erected lining each side of the river below all of the falls. The division of the total fall of 236 feet into four lesser falls facilitated the distribution of the power in comparatively small amounts to a large number of mills without the economic loss that one sees at Niagara, where the smaller consumers discharge the water at whatever height is convenient as long as they obtain all the power they need. In practically all cases here, the wheels were located at the bottom of the gorge in a position to utilize the entire fall. From these wheels the power was transmitted through ropes, belts, gears and shafts by devious paths throughout one or more buildings to the machinery. In some cases the machinery was located in a position to afford simple driving mechanism at the expense, perhaps, of economic handling of material; in the other cases, and more, the reverse condition obtained. Long lengths of shafting were driven from one wheel without mentioning or attempting to ascertain the total or average number of belts, ropes and gears. These locations near the falls did not afford convenient railroad facilities.

When the water power was all appropriated, and the introduction of the steam engine and railroad afforded a new source of power, new establishments were located so as to avail themselves of the advantages of a railroad siding or yard. This effected a considerable economy in handling material unavailable to the water power establishments. The builders of these places, following the "practice based on experience," installed one large engine for each establishment and wasted power lavishly on transmitting mechanisms.

Even with the early introduction of electric motive power, the old practice clung on tenaciously on the basis of "experience," "common practice," "reliability," (such as a large unit and many belts *may* possess in greater amount than the small direct-connected units), "simplicity" (as it appeared on paper), "less first cost" (when the investment for mechanisms was already made), "economy cf operation of a large as compared with a small machine," (disregarding friction losses of transmission as they were at that time unknown and indeterminate), etc., etc.

We are now in a new era as regards industrial power application and the purpose of this paper is to describe the methods of solving the present day problems.

The method of determining the motive power equipment of electric railroads is fairly well known. The route is mapped, showing all grades, curves and stations. A tentative schedule is laid out and calculations are made to determine the extent and duration of power demands upon the motors. Certain severe demands are doubtless found which, if insisted upon, require very large motors as compared with the average demand. The schedule is, however, modified to materially reduce some demands and to increase others. After most careful analysis a schedule and a type of motor are selected which will work together in harmony to accomplish a satisfactory trip with a motive power equipment of moderate size and with a fairly uniform demand upon its staying powers. To accomplish this harmonious result the railway man modifies his first schedule in such particulars as are found to demand poor design ·of the motors and the motor designer selects such a design of motor and equipment as will most nearly approximate a uniform loading when working according to the schedule.

The method of working out the motor equipment of an industrial establishment is not dissimilar to that of a railroad. In the first place the superintendent selects his machines and arranges them in his building as will best facilitate the handling of the material, afford the best light, occasion the least danger from accident, and to the greatest degree obtain economy of production. He states the general features of operation of each machine under different working conditions, the time it is run, the kind of material it handles, its relation to other machines, etc. This arrangement is then submitted to the engineer for analysis, criticism and suggestion.

First the engineer considers the power requirements of each machine individually. Rotative power is the product of torque and

speed, work the product of power and time. Speed-torque time characteristics must be determined for each machine. This requires tests and calculations in addition to the statements of the superintendant as to the hours, use and other conditions of operation. This data may be secured in some one of several methods or possibly checked by two of them. Sometimes the manufacturer will furnish guaranteed performance curves or statements. This has been the practice of some manufacturers of electrical apparatus for many years and is being required more of other manufacturers. Furthermore, the facility of making accurate tests by means of electric motive power and electric instruments has brought the matter of testing within the means of the smallest manufacturers. Usually the central station company is glad to co-operate in making tests on apparatus which, when sold, will require electric energy to operate, the manifestly wise course in a broad business policy. Centrifugal pumps and blowers are notable examples of machines, the performance of which will always be guaranteed by the manufacturers. Frequently the size of the motor will be recommended by the manufacturer, but this should not be relied upon. Some recommend a small motor to indicate an efficient machine and trust that the user will not overload it; others recommend a motor of excessive size on the theory that the user will always overload his machine and it is better to have too much rather than too little power. Either practice is manifestly bad. With the earnest co-operation of the electric motor manufacturers, the data and recommendation of the machine manufacturers is becoming much more reliable.

A second method is sometimes used when power is distributed through shafting from one steam engine or electric motor. This is to measure by means of indicator cards or meters as the power may require, the total power input under more or less known varying conditions. Where the friction is apt to be as great or greater than the load, the power determination is only an approximation likely to be misleading, and if no better determination can then be made to aid in the motor selection, a careful check should be made as soon as a better method is available. By replacing the machine by a prony brake and measuring the effective power output when the power input is the same as with the machine on, the varying friction losses can be eliminated and the real power output determined.

A third method of determining the performance is to measure the torque directly by means of a simple dyanometer. This method is scientific and is often of great value. It is used to obtain starting

torque, which is difficult to obtain otherwise, and the running torque of slow-speed machines and others whose torque is constant and whose work is proportional to the speed. Examples of machines which can be advantageously tested this way are elevators, whose starting torque exceeds the running torque by approximately the ratio of the static to the running friction of the gearing, and tumblers whose low speed makes it possible to make complete tests. In the case of elevators this must be supplemented by calculations when a certain specified rate of acceleration must be effected. Reciprocating machines with heavy parts alternately accelerating and decelerating cannot be tested practically by this method. A transmission dynamometer can be used in a wide variety of machines.

A fourth method is by calculations from the general data concerning the work to be done by the machine. An interesting example of this is a hoop machine, used to press the hoops tightly down on kegs and barrels. It was learned that a 7.5 hp motor was driving a similar machine satisfactorily in one place, a 15 hp motor in another, but no test was obtainable. The size of the hoop, the least angle of curvature against which the hoop was forced, and the speed of the press were measured. It was first calculated that eight horse-power was sufficient to break the hoop under the conditions obtaining, and then that a two horse-power motor with suitable flywheel would be amply large enough to perform the work. Experience with this machine has demonstrated the accuracy of the calculations and the ability of the motor to do the work satisfactorily.

A fifth method is to drive the machine by means of an electric motor, and from suitable meters connected in the line to determine the power input of the motor under all working conditions. Then from the known performance of the motor or by making further tests on the motor with a prony brake, the exact power required by the machine may be easily calculated. This is in most cases an ideal method and is often used even for machines normally driven from a line shaft or a steam engine by running temporary wires and setting up a motor to drive the machine for the test. In this way an entire establishment, driven by one motor through long shafting, can be accurately studied for individual motor application. Generally two test motors can be selected which will have sufficient range for accurate tests of the entire plant.

By means of a graphic recording meter running at a high rate of speed, an exact record of the instantaneous power required throughout the cycle of operation of any machine, such as a shaper

or group of machines can be obtained. This affords a basis of study to properly equip each machine and also to run an entire shop most economically. It shows the comparative power required by an old and new style machine; for instance, whether a machine is over-counterbalanced, whether the operatives are slow to begin work and quick to shut down their machines. Speed indicators, stroke counters, graphic stroke indicators, dynamometers, engine indicators, prony brakes, indicating, integrating and graphic recording electric meters; these are some of the more important tools used.

It is important, especially in old plants which are being modernized, to examine each machine with the idea of replacing it if possible with a new machine of enough greater efficiency to warrant the investment and with the idea of correcting mistakes in operation which may have crept into practice insidiously and remained unnoticed. To illustrate, on one plant a centrifugal fan was found running at such speed that the damper in the supply pipe was always partly closed. A change of one-half inch was made in the diameter of the motor pulley and satisfactory results obtained with a power consumption of only 71 percent of that formerly used and a saving of $100 per month. Again a 130 foot turbine pump was found pumping against less than 60 feet static and about 20 feet normal friction head resulting in great losses and unsatisfactory service.

Of prime importance is the matter of speed variation, for upon this requirement, more than any other, depends the choice between the direct and alternating-current systems, if both sources of power are available from the central station. Direct-current motors can be obtained with a range of speed of as much as one to six, capable of operation at full-load and nigh efficiency at any speed within this range. Two or three-speed alternating-current motors may be obtained in the larger sizes with good efficiency, but as a rule, variable speed alternating-current motors are of such low efficiency at the slow speeds that they cannot be used economically for continuous service at the slow speeds. If a large proportion of variable speed motors is required, then the direct-current system is desirable. If few or none of the machines require variable speed alternating-current is preferable, chiefly on account of the simple and rugged construction of the motors. There are either no moving contacts or else slip rings only with low potential across them. The only wearing parts are the two shaft bearings; the only attention required is the oiling of the bearings and the general cleaning of the

machine. Alternating-current motors have, in general, more nearly constant speed than direct-current motors. They are capable of being loaded momentarily to a standstill without injury, have a

MOTOR DRIVING VENTILAT-
ING FAN

Light starting conditions
—continuous operation at
constant speed.

maximum torque of two and one-half to three times full-load torque, can be started in the smaller sizes without a rheostat by simply closing the line switch.

With the general data together and the system chosen, the selection of individual motors begins. The simplest requirements of a motor are to start with light load (from zero to full-load torque may be considered as light) and to run at moderate and constant speed with fairly uniform load for considerable periods of time. This sort of load is obtained from such machines as drill presses, lathes and milling machines in a machine shop; grinders, tumblers and blowers in a foundry; grinding mills, cleaners and conveyers in a feed, flour or
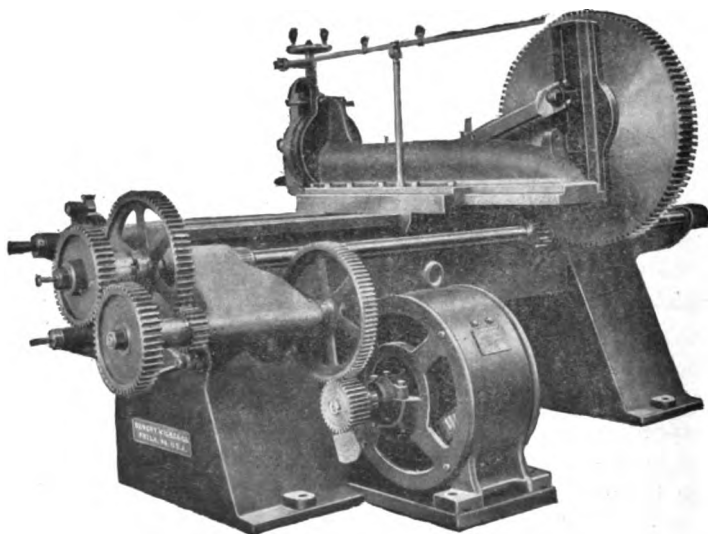
FIG. 2—MOTOR DRIVING SHAPER
Medium starting conditions—adjustable speed.

spice mill, brewery or grain elevator; looms or sewing machines in a textile factory; burnishers, setters and sewing machines in a shoe factory; sausage cutters in a meat market; a continuous press

in a printing shop, etc. For this service a shunt wound direct-current motor or a squirrel-cage alternating-current motor are best suited and are the cheapest forms of direct-current and alternating-
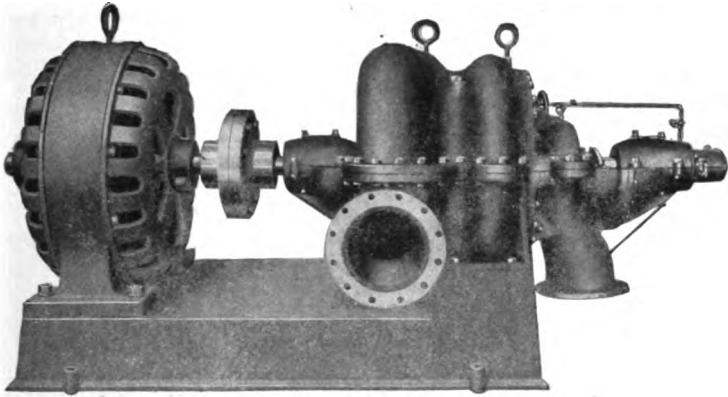
FIG. 3—MOTOR DRIVING CENTRIFUGAL PUMP
Continuous operation at high speed.

current motors respectively. For similar characteristics, except that very high speeds are required as for high pressure blowers or turbine pumps, a special direct-current motor should be used which is
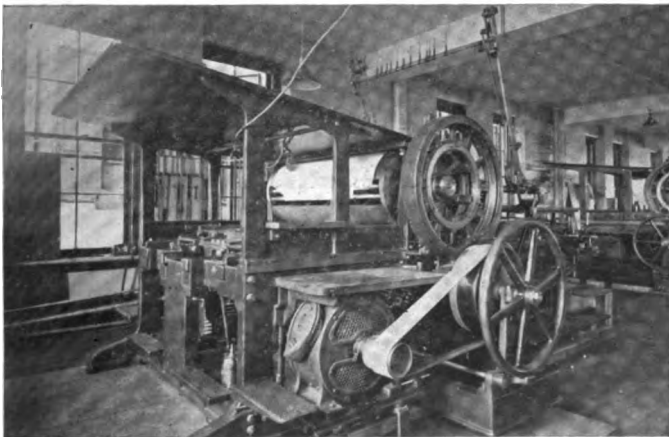
FIG. 4—MOTOR DRIVING CYLINDER PRINTING PRESS
High starting torque—continuous operation at constant speed.

designed especially to give good commutation with a weak field and consequent high speed.

When a high starting torque is required with constant speed

operation, a direct-current motor with compound-wound fields or an alternating-current motor with wound secondary should be used. Air compressors or displacement pumps require full-load torque at starting; elevators require as much as 50 percent in excess of full-load torque. A direct-current motor which is very frequently started and stopped or one which has a very fluctuating load should always be compound-wound in order to minimize commutation troubles. Neither of these conditions adversely affect a squirrel-cage alternating-current motor.

Series wound direct-current motors and induction motors with wound rotors are largely used for crane or hoisting work. They are variable speed motors, the speed being inversely proportional to the
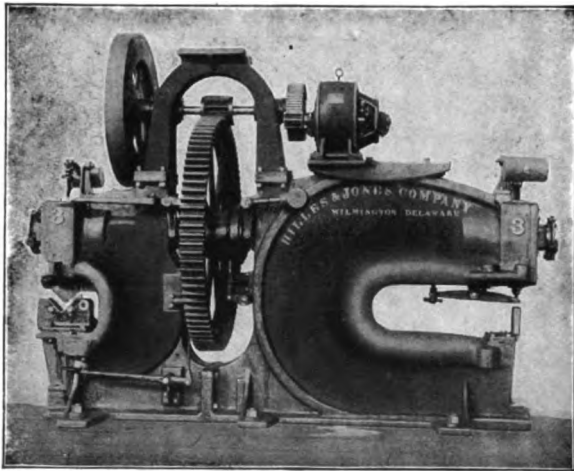
MOTOR DRIVING COMBINATION PUNCH AND SHEAR MACHINE
Typical application using fly-wheel.

load. Similarly synchronous alternating-current motors are seldom used because, although rigorously constant in speed within the limits of speed variation of the supply generator, they are more expensive and difficult of control. In a large plant requiring both alternating current and direct current and supplied with alternating-current from the central station a synchronous motor—direst-current generator set has many advantages.

A thorough understanding of the principles of mechanics and familiarity with mechanisms is essential to the best results in motor application. As an illustration, with machines having intermittent sudden demands, such as power presses and shears; with heavy reciprocating parts such as printing presses, and others of like char-

acteristics, it is almost always possible to use a relatively small motor by including in the mechanism a suitable fly-wheel and selecting a motor with variable speed tendency. With this combination the motor can easily bring the fly-wheel up to speed and then when the load comes on reduce its speed so as to throw the burden upon the wheel. Reference has already been made to the hoop machine which shows the value of the fly-wheel. Motor-generator sets with which are combined large fly-wheels are coming into general use for equalizing the demand from the line in cases where the load is of a violently fluctuating character, such as on large mine hoists, reversing rolls in steel mills*, etc.

The correct selection of the best method of transmitting the power from the motor shaft to the machine, whether by coupling, gears, chain or belt, requires not only a knowledge of possible arrangements but acquaintance with their comparative advantages and disadvantages, adaptability and limitations, and above all the essential requirements for their successful operation.

MOTORS DRIVING SPINNING FRAMES
Illustrating individual drive.

In most establishments conditions exist which do not warrant the installation of a separate motor for each machine, but under which the most satisfactory operation obtains through the arranging of at least part of the machines in groups driven from line shafts, each shaft driven by a motor. This arrangement is termed group drive and may be extended to include the entire establishment in one group. The following principles determine the selection between individual and group drive.

Individual drive is correct when, 1—the cost of installation is less than for a group drive; 2—when the saving in operating cost of

*See article by Mr. W. A. Dick in the JOURNAL for February, 1908, Vol. V., p. 68.

the individual drive is more than enough to pay the additional fixed charges of this form; 3—when the convenience of operation is worth the additional cost which may be involved. The discrepancy in cost between group and individual drive is not as great as might be at first supposed. For example, assume the case of a group of twelve machines each requiring about one hp, four requiring to be reversible and four requiring variable speed. The cost of drive for these machines using one 10 hp motor, 60 feet of line shaft, countershafts, pulleys and belts is about $590. The cost of individual motor drive using twelve one hp motors of required characteristics, having
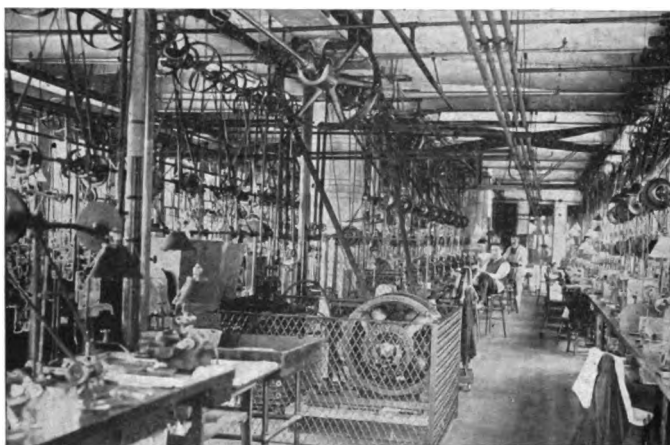
MOTOR DRIVING LARGE GROUP OF BUFFING AND GEARING LATHES
Typical illustration of group drive—as contrasted with individual drive, using small motor on each machine and thereby eliminating the obvious complication of countershafts and belting.

a speed ratio of about 1 to 1.25, geared or belted directly to the machines, complete with rheostats and switches is about $965, a difference of only $375. This difference is much less where so called constant speed motors alone are used. It would not take long for either the repair or maintenance account, or the increased and better production to make up the difference in first cost. Furthermore, if these machines were distributed over a large space, with many additional bearings, pulleys, belts and feet of shafting, the cost of the group drive would soon exceed that of the individual drive.

The saving in operating cost of individual drive depends on, 1—the difference in fixed charges, usually in favor of group drive; 2—the difference in efficiency of the motors, this in favor of the large group motor if *run at high average* load, otherwise in favor of the

smaller motors well loaded when running at all; 3—the number of bearings loose pulleys, belts and gears eliminated by the use of individual motors; 4—the average hours daily use of machines. The friction losses of the old style establishment run from 25 to 75 percent of the maximum load, much of which can be eliminated by means of individual drive. In one machine shop where tests were made, there were two line shafts each about 75 feet long, new roller bearings, carefully aligned, well proportioned belts and pulleys, all carefully attended to, driven by two 15 hp motors. The friction loss of motors, shafts and countershafts amounted to 5 hp and 6.6 hp; the load with all machines running light, 16.2 hp and 16.4 hp The maximum load recorded in six months' operation of these, to gether with a five hp. motor on another shaft, several motors on a crane and several individual machine motors has been 40 hp.

In another establishment there were two steam engines in one room driving line shafts on several floors of three buildings. One engine of 35 hp rated capacity drove 480 feet of three-inch shafting with 56 bearings, four pulleys, ten pair of heavy cast iron gears, 50 feet of ten-inch belting, and a little light machinery. This machinery is now geared directly to nine alternating-current motors aggregating 35 hp capacity. The other engine of 75 hp rated capacity drove 262 feet of three-inch shafting, 47 bearings, 37 pulleys, four pairs of gears, 415 feet of double belt averaging ten inches in width, and 14 machines, of which seldom more than three are operated at the same time, although the shaft ran 24 hours a day. These machines are now driven by fourteen motors, aggregating 101 hp capacity at a gratifying reduction in cost. At present values the engine drive would cost more than the electric drive and has a scrap value now nearly equal to the cost of the electric drive.

Convenience of operation is a hard thing to capitalize. It includes such features as cleanliness, more light and less shadows, less noise, more uniform operation, quick and easy control of speed, less danger from moving belts or accidental starting, reliability, flexibility under present or unforseen conditions, location and relocation of machines without thought of power supply, simplicity of remote control and automatic operation, freedom from annoyance and delay due to loose and broken belts, ability to support the motor from the floor, side wall or ceiling, the two latter methods making available the floor space otherwise occupied by motors or vertical belts. Some manufacturers have been able to partially determine its value by the increased production of their factories which has amounted to from ten to 25 percent with equal or less power cost.

A 60-CYCLE GAS-DRIVEN POWER STATION

OPERATING RESULTS AT THE PLANT OF THE UNION SWITCH & SIGNAL CO.

J. R. BIBBINS

THERE has been so much speculation within recent years on the possibility of success in operating 60-cycle gas-driven alternating-current generators in parallel on a fluctuating industrial load that some actual experience and results from a modern plant would seem to be of value and interest at this time. The reasons for selecting the Swissvale plant of the Union Switch & Signal Company are noted below. All of these characteristics are rarely found in a single plant:—

1—It was one of the very earliest 60-cycle plants installed in this country, yielding eight years' experience to date.

2—Its operation at all times has been representative of the average industrial plant on 24-hour service.

3—Its growth has been along lines identified with good engineering.

POWER DEVELOPMENT

To the author's best knowledge, parallel operation by gas engines on a commercial scale was first wrought out in America in the Pittsburg district. As early as 1900-1-2, three plants* were equipped with engines ranging from 125 to 300 hp of the vertical single-acting type. The fact that all of these machines are to-day in regular service, is the best evidence of the fact that the preliminary experiments of 1899 at East Pittsburg were successful. These experiments were conducted on engines of the vertical, single-acting type, in the effort to solve parallel operation. After various attemps at solid coupling, the result was a recommendation of flexible drive for 60-cycle work, and all plants were so equipped. Generator spiders were mounted on loose sleeves with helical spring couplings. One unit in each plant, however, was solid coupled for operating alone.

The old Swissvale plant has been in continuous service night and day up to 1908, when, by reason of extensions to the manufacturing plant at Swissvale, an enlargement of the power plant be-

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*The Westinghouse Machine Co., East Pittsburgh, 900 hp.; R. D. Nuttall Company, Pittsburgh, 500 hp. (equipment later doubled); and the Union Switch & Signal Co., 500 hp. (equipment later doubled).

came necessary. The original equipment was transferred to a new generating station designed primarily for the horizontal type double-acting engine. This new power station (Fig. 1) went in service May 11th of this year and operates along precisely the same lines as the old. In fact, both single-acting and double-acting units are in daily service in parallel on the same load.

OPERATION

The normal shop load at Swissvale extends through 24 hours with sustained morning and afternoon output and an all-night load 50 percent lower, yielding an average loading factor for the entire
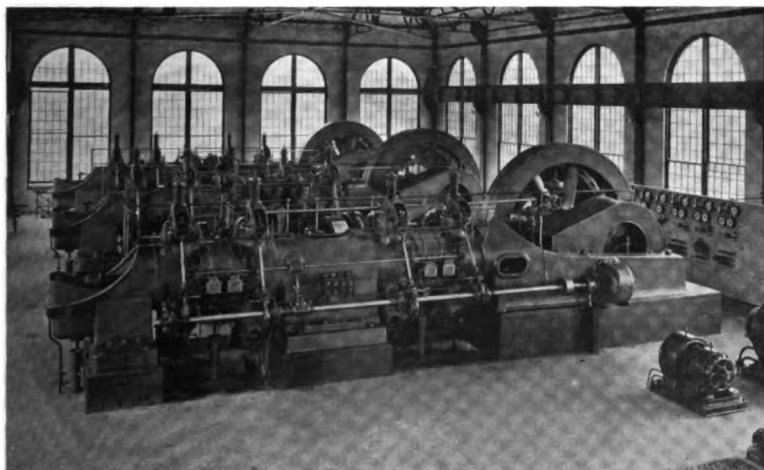
FIG. 1—NEW 2 000 HP POWER STATION OF UNION SWITCH & SIGNAL COMPANY
Three 23½x33 inch, 150 r.p.m., double-acting units; three 350 kw 60-cycle generators, solid coupled. Small vertical, single-acting units, spring coupled. All units in parallel on common bus-bars.

plant of about 40 percent of its capacity. While the hourly output is fairly uniform, instantaneous fluctuations are incessant, due to application of large motors, probably averaging 25 percent above and below mean. There is also a 24-hour lighting load often carried from the power bus-bars. Although voltage regulators are employed, the fact remains that any such apparatus, however sensitive, would be quite incapable of compensating for inherent irregularities in turning moment at the shaft. The service at this plant is such as to impose a most satisfactory test of 60-cycle parallel operation. Incidentally, it may be noted that some of the units have a record of seven weeks' continuous operation.

The character of attendance at Swissvale is normal—a chief, trained in gas engine work, and assistants educated at the plant. In the old plant, two men operated 1 000 hp in gas engines, together with air compressors. At present, three men have charge of double that capacity (two on night shift).

The operation of starting, synchronizing, distributing load, etc., are practically identical with steam practice. At the board, a synchronizer and the usual lamps determine the time of switching. Any of the operators are capable of paralleling with the assistance of a second man to depress the governor by hand while adjusting speed. A separate adjustment of the governor springs provides for equalizing load. Starting is accomplished automatically by compressed air, one valve controlling all four inlets to individual combustion chambers. Usually 50 to 60 pounds pressure is sufficient for the purpose, although high pressure tanks are kept continually charged. Normal ignition usually commences on the third revolution. A centrifugal safety-stop at the fly-wheel rim prevents over-speed by tripping a switch which opens the ignition circuit. Both cylinder and journal lubrication is automatic. The oil supplied to each engine, and the cooling water to jackets, are each controlled by single valves, so that in starting an engine there are but five operations: 1—Closing igniter switch; 2—operating compressed air valve; 3—opening gas throttle; 4—opening water gate; 5—and oil valve. These present no complexity, even in emergencies; in fact, the engine is favored in comparison with steam-driven condensing units.

RELIABILITY

Automatic lubrication was brought about by the absolute necessity of avoiding carelessness of operators. Owing to the extreme temperatures and lack of presence of moisture, as in steam cylinders, ample lubrication is imperative. And although double-acting pistons are supported free from the cylinder walls by front, center and rear crossheads, a stoppage of lubricant for any length of time would likely result in scoring of cylinders. The mechanical sight-feed system, driven by the engine itself, avoids this danger, and incidentally largely reduces the quantity used by injecting cylinder oil only on the induction stroke, when it is easily spread over the cylinder surface before combustion takes place. Similarly, the continuous gravity filtration systems for engine oil have practically eliminated troubles with hot bearings and have reduced the con-

sumption of lubricating oil practically to the point of leakage, evaporation and waste.

Ignition, a second vital point in gas engine operation, is rendered reliable by the use of two or more igniters in each combustion chamber, all fired at the same instant, but separately fused, so that a troublesome igniter can be isolated. Incidentally, it is a matter of good fortune that the more perfect combustion produced by igniting the gases at different points, results in from three to four percent increase in power, as shown by tests with one and two igniters respectively. The effectiveness of this system may be measured by the results produced. The ignition is quite uniform. A remarkable record of blast furnace gas operation, Fig. 2 (discussed later), also shows this feature.

REPAIRS

It is the policy at Swissvale to spend enough annually for repairs to maintain the equipment at its original state of efficiency. In other words, to forestall depreciation, except in the form of obsolescence. The maintenance account, therefore, includes items which might have been avoided had it been the intention to put the plant out of commission after a comparatively short period of service. Considering the original equipment of vertical gas engines, this maintenance acount for the sixth and seventh year of service averaged about four percent of the plant valuation—equivalent to 25 years' life—by no means an abnormal rate of depreciation.

The following notes indicate the normal repair work necessary. The vertical cylinders have not yet required reboring. Exhaust valves require regrinding once in six months. Igniter points on the small engines are examined and repaired twice each month. This is due to replacing platinum by iron wire points which, of course, wear down at a much faster rate. With the old platinum points, engines have run seven weeks continuously without shutting down for replacing igniters. In the horizontal engines no points are used, and the igniter terminals, lasting several years, require facing not more than once in three months. Jackets require cleaning about once a year. Vertical engine bearings are taken out once a year; horizontals, as occasion demands. Horizontal piston rod packings or piston rings, have not yet been removed, having been in operation only eight months. In general, there is no indication that alternating-current parallel operation is in the least responsible for any greater share of the repair items than in the operation of direct-current generators.

COST OF POWER

Owing to the difficulty of segregating some cost items from blanket accounts, we cannot obtain from the records of the old Swissvale plant a schedule of power costs exactly comparable to central station practice. However, a fairly accurate analysis may be made from the records as presented in Table I. This data corre-

TABLE I—COST OF POWER—U. S. & S. CO.

Capacity of plant..900 hp., 500 kw.
Number of units...5
        Type of units: Vertical, single-acting, spring-coupled.
Maximum loading factor, January, February and March..44 percent.
Gas per kw-hr. (according to quality)....................22-25 cu. ft.
Approximate cost of plant..............................$100 per kw.
        Average Cost of Operation for 50 percent Loading Factor;
                Output, 2,190,000 kw-hr. per year.
Fuel at 15 cents per M. cu. ft...................................$ 5,150
Water (estimated, 10 percent make up)........................   300
Oil and Waste.. 1,000
Labor (3 men day; 2 men night)............................... 4 200
Repairs and Maintenance (4 percent valuation)................. 2,000
                                                            ‾‾‾‾‾‾
    Total Operating Cost—0.58 cents per kw-hr.................$12,650
Fixed Charges:
    Interest, 5 percent; Taxes, 1 percent....................... 3,000
    Insurance (Building Fireproof)...........................   ......
                                                            ‾‾‾‾‾‾
                                                              $15,650
Total Cost of Power............................0.71 cents per kw-hr.

sponds to an average station loading factor of fifty percent—fuel at 15 cents per thousand cu. ft., and other items of cost prorated from the present schedule. A fixed charge of ten percent, for maintenance, interest, etc., has been included. On this basis the old 1 000 hp plant was able to deliver power at switchboard for 0.58 cent operating, and 0.71 cent per kw-hr total. The figures clearly define the question of commercial cost as well as thermal efficiency, and are verified by the actual records.* No records under comparative conditions have yet been obtained from the new horizontal plant as it is at present very lightly loaded and has not been in operation a sufficient length of time to yield a fair average.

GOVERNING

Present interest in the Swissvale plant centers largely in its

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*Data on operation furnished by Mr. J. G. Schreuder, 2nd Vice-President and Consulting Engineer.

ability to give suitable regulation for 60-cycle work. Some results in this line will, therefore, be of interest. The problem of gas engine governing involves several factors: a—simple speed regulation with varying load; b—cyclic speed variation resulting from variable crank effort; c—governor lag behind admission; d—possibility of missed power stroke from back fire or igniters. Contrasting the steam turbine, steam engine and gas engine, we find very dissimilar conditions. In the turbine, the governor and the resultant dynamic effort change simultaneously; i. e., there is no time lag. In the steam engine, the governor acts in the same stroke as the previous cut-off ; i. e., assumes a position determined by previous admission— less than 90 degrees lag. In the simple four-cycle engine, the governor lags two strokes behind the admission, but with the tandem cylinder arrangement, this lag is reduced to one stroke. Fortunately, with the fly-wheel weight necessary to absorb cyclic variation, this lag is comparatively unimportant and may be observed only in the over-travel of the governor during extreme load changes, as shown later.

In view of this unavoidable lag, governors tending to anticipate speed change (such as the isochronous or the inertia type) are evidently least suited as introducing needless sensitiveness, or instability. On the other hand, the simple centrifugal type carefully designed for the work in view, has proven quite suitable, especially those types in which the centrifugal force of the weights is resisted by direct spring tension without intervening levers or contacts (such as the Hartung, Jahns, etc.).

In most large gas engines the relay system of governing is employed. Two important elements enter into this relay system: First, the regulator is entirely relieved of the work of moving heavy valves, particularly necessary when they are fouled by tar, dust or other foreign matter. Thus the effect of *valve friction is entirely eliminated*. Second, control of motive fluid is possible right at the point of entry to the cylinder. In the early designs of multi-cylinder engines, a single governor valve was employed to control all cylinders, resulting in a large quantity of mixture lying idle between valve and outlying cylinders. Before any further governing could be accomplished, this idle mixture evidently had to pass through the cycle, the time element involved varying with the distance of cylinders from governing valve; and, most important, a single backfire would vitiate the incoming mixture for all cylinders. The present system of governing at inlets only, is evidently the direct reverse,

embodying the very important point that there is practically no idle mixture between governor valve and inlet; i. e., that the supply at each stroke is exactly equal to the demand—thus minimizing the effect of backfires.

Mixture—There has been much discussion upon the merits of the constant versus variable quality system of gas engine regulation. The one governs by throttling a mixture of most effective proportions; the other, by introducing more or less excess air according to the load, to fill the cylinder and maintain constant compression. Quite recently a statement was publicly made, which questions the merits of the constant quality system for conditions of lean gas and light loads. Here is involved the crux of the whole problem of regulation—absolute uniformity of combustion under all conditions. Evidently parallel operation would be a failure if uniform combustion could not be guaranteed.
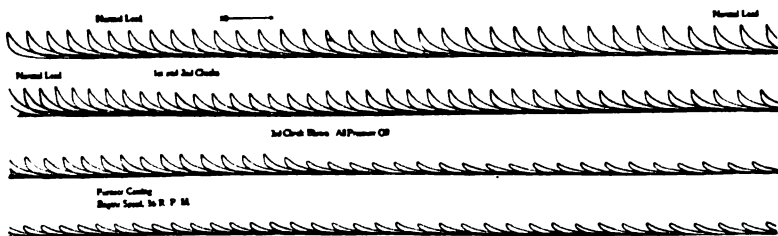
FIG. 2—TYPICAL CONTINUOUS INDICATOR CARD RECORD FROM 3 000 HP BLAST FURNACE GAS ENGINE
From full to no load during furnace operations, showing uniformity of ignition and combustion.

Without further comment, it is believed that the continuous indicator record shown in Fig. 2 will contribute most satisfactory evidence on this point. This record was obtained at the Carnegie Steel Works on a 3 000 hp., four-cycle tandem double-acting blowing engine. It covers a complete cycle of blast furnace operation from full load to no load. The original record, 40 feet in length, comprises 396 cards without the least evidence of misfires, back-fires or incomplete combustion, either at full, half or no load. To the author's mind, this record refutes in the most convincing manner the criticisms alluded to. Similar results were obtained at Swissvale on natural gas.

Backfires—Another exaggerated gas engine trouble is the effect of back-fires on the uniformity of power and crank effort. Fig. 3 shows a sequence of cards following a back-fire, which illustrates

the point at issue in a most fortunate manner. In card *A* the mix-ture fired on induction stroke from some unascertained cause, and the corresponding power stroke *B*, was missed. But on the suc-ceeding power stroke, a card above normal mean effective pressure was obtained, followed by one of maximum mean effective pressure. Net result—one missed stroke and a slight over-reaching of the gov-ernor. This same effect would be produced by a misfire, but as will be shown later, a single back-fire or misfire is hardly discernible in engine operation. If continued, the defective cylinder end would, of course, have to be isolated and load reduced accordingly. But this is an extremely rare occurrence and concerns the engine de-signer—not the operator. Conservative engineering dictates a lib-eral factor of safety in alternating-current gas engine work over the
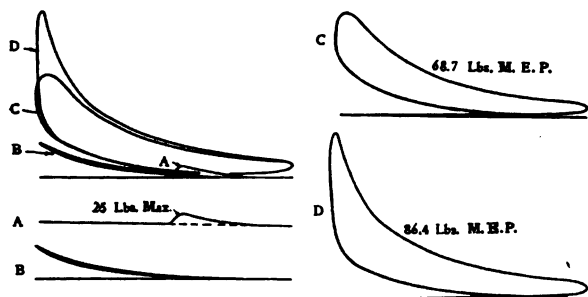
FIG. 3—SEQUENCE OF INDICATOR CARDS FOLLOWING BACK-FIRE

limits of angular deviation specified by the electrical companies for safe practice—a factor of safety sufficient to cover ordinary con-tingencies, such as mal-adjustments, misfires or back-fires. Con-versely, it is a fortunate fact that in normal running, the angular variation is relatively low, and hence all the better suited to parallel operation.

 Tachograph Records—These points are clearly illustrated in some tachograph records, Fig. 4, showing angular variation, taken by a prominent British engineer* from a double crank two-cylinder, double-acting engine (two 24x30 inch, 155 r.p.m.) with cranks at 180 degrees—equivalent in arrangement to the cross-compound steam engine, and, in sequence of power impulses to the single-crank, double-acting, tandem gas engine discussed. The subjoined legend is self-explanatory. The following facts may be noted: First—Two power strokes followed by two misfires result in twice the frequency of variation of one power followed by one missed stroke, both increasing the degree of irregularity about four times.

*Mr. H. A. Humphrey.

The former corresponds to one cylinder out, the latter to the forward end of each cylinder, or rear end. Second—Two missed ignitions result in four times greater irregularity. These changes corre-
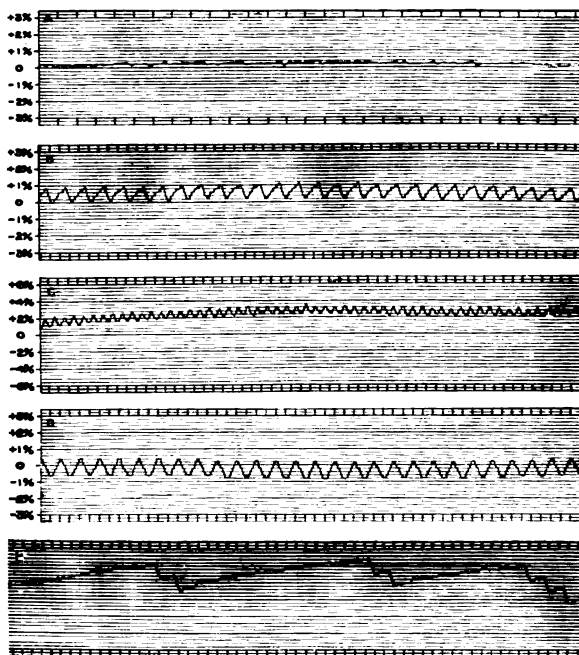
FIG. 4—RECORDS OF SPEED VARIATION ON TWO 24x30 INCH, TWO-CRANK, DOUBLE-ACTING GAS ENGINES OF 600 H.P. CAPACITY

A—Engine on full load; normal mill service; governing by throttling mixture admitted to cylinder; degree of irregularity, 1/500.

B—One end of one cylinder cut out by stopping ignition; all three cylinders taking mixture and compressing as usual; three-quarters load; irregularity, 1/110.

C—Opposite end of each cylinder cut out; all cylinders taking mixture and compressing as usual; approximately one-third load, irregularity, 1/100.

D—One cylinder only working; other cylinders taking mixture and compressing as usual; approximately one-third load; irregularity, 1/100.

E—Effect of missed ignitions on one end of one cylinder; two and three missed ignitions were made.

The vertical division lines denote revolutions.

spond precisely to the experiments noted below from the Swissvale engine.

As a compartive curiosity, Fig. 5 has been reproduced from a

tachograph record taken on a tandem steam engine driving a cotton mill. So much has been said about the close regulation necessary in cotton mill work, that this record is of extreme interest. The instrument shows over 4.6 percent variation $+$ mean, or $\frac{1}{10}$ irregularity, partly due, of course, to the low speed. This, however, is reduced to two percent $+$ mean, or $\frac{1}{20}$ by transmission through two gear, one rope and one belt drive. This may be compared directly with record A, Fig. 4, which was taken by the same observer on the same instrument in the same mill and driving the same machinery by gas engine in place of steam engine. It is exhibited not so much as representative of steam drive, but as illustrative of the wide discrepancy between conjecture and practice. All of the above records
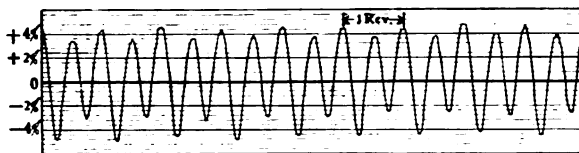
FIG. 5—TACHOGRAPH RECORD ON TANDEM STEAM ENGINE
DRIVING COTTON MILL

were obtained from a Horn recording tachograph with calibrated springs.

Speed Variation—Speed and deviation records have recently been made at Swissvale from the three horizontal engines installed, without any attempt to adjust the valve mechanism of the engine and represent actual operation as experienced during the last six months. Fig. 6 shows the apparatus employed—a Moscrop recorder for speed variation and a constant speed magneto generator for obtaining records of angular deviation on the face of the fly-wheel. Speed regulation is shown in Fig. 7, each explained by the legend beneath. On regular shop load, the regulation is all that could be desired. On instantaneous change (no load to full load and vice versa) the governor overtravels considerably, which is a characteristic of all governing systems having an unavoidable lag. The net speed variation, however, after subsidence of the surge, is normal, averaging 2.6 percent; momentary, 5.6 percent above or below mean.

Note from record C that the engine is practically unaffected by one or two missed ignitions. With one end cut out it drops momentarily 4.75 percent below mean speed, but recovers in about one

minute.   Up to this point, no fluctuation was visible at the switch-
board wattmeters.   With an entire cylinder out, E, Fig. 7, some
cyclical fluctuation was noticeable with an average momentary speed
change of 6.25 percent, final two percent below mean.   Record *Bb*
shows the effect of paralleling at the instant of shifting load; first
the rise in·speed at *3* due to the subdivision of load, then the fall *4*
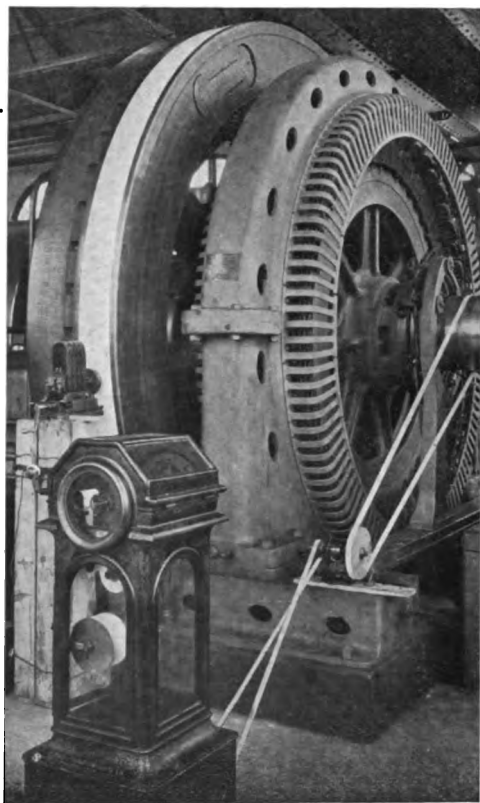
FIG. 6—VIEW SHOWING METHOD OF TAKING MEASURE-
MENTS OF SPEED VARIATION

as the entire load was thrown on the new engine.   No troublesome
surging of speed takes place in the normal operation of the plant,
and with ordinary care, the machines may be paralleled without
noticeable fluctuation at the meters.

    Angular Deviation—The fly-wheel records taken by the instru-
ment above mentioned, indicate a variation of about *two electrical*

degrees during the revolution at a load corresponding to about 75 percent of the engine rating. Although about one-third the deviation permitted by generator builders, it is higher than normal, which may be explained by the fact that the valve mechanism had never been accurately adjusted by indicator. Recent cards taken simultaneously, show the cylinders to be considerably unbalanced; i. e., work distributed unevenly. This condition may, of course, be en-
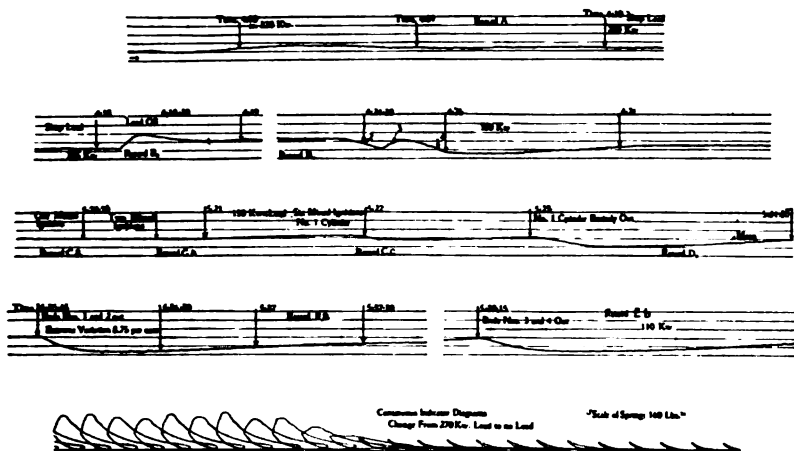
FIG. 7—RECORDS ON 23½x33, HORIZONTAL TANDEM, DOUBLE-ACTING GAS ENGINE AT
SWISSVALE PLANT OF UNION SWITCH & SIGNAL COMPANY

A—Regular shop load, group drive, lighting, etc., 280-320 kw.
B—(a) Load thrown off; (Bb-1) Synchronizing; (2) Switching engine on load; (3) Two machines building up in speed; (4) All load thrown on new engine.
C—(a) Missed ignition on one end by interrupting the igniter circuit for one power charge; (b) Missed ignition on one end for two power charges; (c) Consecutive missed ignitions for six power charges.
D—(a) One cylinder end cut out by stopping ignition; all ends taking mixture and compressing as usual.
E—(a) Forward cylinder cut out by stopping ignition; all cylinders taking mixture and compressing as usual; (b) Rear cylinder cut out by stopping ignition; all cylinders taking mixture and compressing as usual.
The distance between horizontal lines represents five percent variation.

tirely remedied by proper adjustment of governor reach rods and ignition, as was later done. In one engine the disparity between the mean effective pressure of various cylinder ends, was found to be excessive, one end doing fully twice the work of the other without resulting trouble in paralleling. The fact that these conditions existed without prejudicial effect on the general operation of the plant, is the best evidence of the great desirability of conservatism in design above noted. This disparity in loading of cylinders due to mal-ad-

justment is, of course, encountered in a like degree in steam practice, and with the same results—impairment of regulation.

<div align="center">CONCLUSION</div>

From the preceding discussion it will be apparent that the underlying theme of this paper is "results"—what constitutes modern practice?—how closely have we attained to commercial conditions of operation? The following facts would seem to have been established:

1—The modern gas engine, properly operated, is quite equal to industrial power service even with alternating-current distribution.

2—Eight years' experience points to a normal depreciation rate on the vertical type with every indication of an equally staisfactory future for the horizontal type engine.

3—The operation of either the horizontal or the vertical type presents no greater difficulties than good steam practice, and requires about the same extent and grade of attendance.

4—Ample security is provided in double-acting designs against careless operation by automatic oiling and duplicate igniters.

5—Necessary uniformity of combustion assured.

6—Cost of power generation, with all charges included, relatively low—well below steam.

7—Governing suited to demands of direct-current or alternating-current parallel operation. Speed variation within present requirements. Angular deviation well below steam practice, with sufficient factor of safety to cover ordinary contingencies. Success of solid-coupled, 60-cycle plants practically assured for general commercial service.

APPLICATION OF AUTOMATIC CONTROLLERS TO DIRECT-CURRENT MOTORS—I

ELEVATOR CONTROL

D. E. CARPENTER

THE general term "elevator control" may be understood to include the control not only of elevators but also of skip hoists, incline railways, etc. An automatic control system for an electric elevator should be capable of starting, accelerating, stopping and reversing the motor, each in the least possible time consistent with the safety of the apparatus, and at the same time should securely guard against all probable accidents, such as over-travel and catching or sticking of the car. Magnet switch controllers of the type described in the preceding article are excellently adapted for this class of service. In the arrangement of such a controller for an elevator motor a group of interlocking magnet switches is assembled on a panel along with the auxiliary devices necessary for the proper operation and protection of the motor, the elevator, and the supply circuit.

These controllers are of two classes, known from the method of their operation as automatic and semi-automatic. These two classes are also sometimes designated as the magnetic and semi-magnetic controllers. With an *automatic* controller, reversing, acceleration in either direction, and speed adjustments are directly controlled by magnet switches, the operation of these switches being started and stopped by means of a reversing master switch located at a point convenient for the operator. In automatic elevator control the master switch is located in the car and is connected with the magnet switches by a flexible cable. The *semi-automatic* elevator controller is provided with a mechanical reversing and starting switch mounted on a controller panel and operated from the elevator car by means of a rope running through the cage or connected to a lever in the cage.

With either class of controllers the acceleration is predetermined; it depends on the motor current, and is not under the

direct control of the operator. The acceleration can be arranged to be controlled by voltage drop in the starting resistance or by a series relay as previously explained. In either case the motor and the elevator are automatically protected from too rapid acceleration.

Automatic controllers are most suitable for large motors applied to high-speed elevators, for incline railways, skip hoists, etc.; in fact, for all strictly high-class installations. For small elevators where, for example, the motor is not larger than 20 horse-power, and where a less expensive equipment is desired, the semi-automatic controller is satisfactory.

AUTOMATIC CONTROLLERS

The automatic elevator controller consists of a panel on the front of which are mounted the magnet switches, the accelerating relay (if used), and a double-pole single-throw line switch with enclosed fuses. On a single-speed, four-point controller, nine magnet switches are used— four for reversing, four for accelerating, and one for operating the dynamic brake. In starting a compound-wound motor two of the four accelerating switches can be arranged to cut out the series field in two sections. On a two-speed, four-point controller, one additional switch, making ten in all, is provided for inserting a section of speed adjusting resistance in the motor field circuit. Two-speed controllers are used with shunt-wound motors only.

AUTOMATIC ELEVATOR CONTROLLER, TWO SPEEDS, FOUR STARTING POINTS, ACCELERATING RELAY AND LINE SWITCH

Blow-out coils prevent all injurious arcing. If the acceleration is by drop in resistance, the accelerating relay is omitted from the panel.

The dynamic brake consists simply of a section of resistance short-circuited across the motor terminals immediately after the line circuit is opened. A heavy current flows momentarily through the armature and the brake resistance, and brings the armature quickly and easily to rest.

Resistance—Each controller is provided with ohmic resistance

for carrying the full motor current in starting and accelerating. Each two-speed controller is also provided with a field regulating resistance and a resistance for connecting in series with the motor when passing from high to low speed. The last named resistance prevents a sudden rush of current and consequent excessive dynamic braking caused by cutting out the field regulating resistance when the armature is running at high speed.

Master Switch—A master switch for mounting in the elevator car is employed with each controller. Since this switch seldom carries more than one and one-half amperes and never more than three, the parts are light, and the switch occupies but little space in the elevator car. The handle is moved either way from the center or off position against the action of a strong centering spring, so that it immediately returns to the off position on being released by the operator. The switch handle can be moved a considerable distance either way from the off position before closing a circuit, thus eliminating the danger of inadvertently reversing the motor when moving the handle to the off position. The same master switch is used with the single-speed and two-speed controllers, except that, if the controller is for one speed only, the first and second contacts each way from the off position are short-circuited.

Moving the master switch to the first set of contacts causes the automatic switches to act consecutively, bringing the motor up to full normal speed. With a two-speed controller in connection with a shunt motor, further movement to the second contact causes another magnet switch to cut in the field regulating resistance and give maximum speed. Returning the handle to the center causes all the starting and speed regulating magnet switches to open and the dynamic brake switch to close, thus stopping the car promptly, but without shock. When the motor has come to rest the dynamic brake switch opens. The elevator car moves up or down according to which way from the center the master switch handle is moved.

SEMI-AUTOMATIC CONTROLLER

The semi-automatic elevator controller consists essentially of a rope-operated reversing switch, a knife blade line switch, and two or more automatic resistance switches. The magnet switches, the line switch, and the controller terminals are mounted on the front of a slate panel. The starting resistance

and the reversing switch are mounted on the back of the panel. With this arrangement the acceleration is by the resistance drop method and a dynamic brake can be provided or omitted as desired. If the voltage fluctuates over a wide range, the use of a series accelerating relay is advisable.
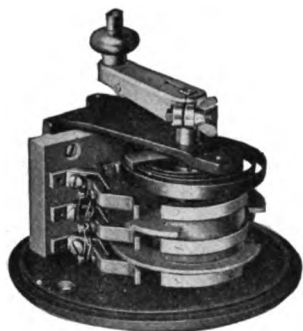
MASTER SWITCH WITH COVER REMOVED

Reversing Switch—The contacts of the reversing switch are so arranged that the motor circuit is always opened by one of the magnet switches and not by the reversing switch. This object is accomplished by so arranging the contacts on the reversing switch that, in stopping, the operating circuit of the magnet switches is opened first, thus allowing these switches to drop out before the reversing contacts open. Very little arcing, therefore, occurs in the reversing switch. Blow-out coils protect the contacts of the magnet switch which opens and closes the motor circuit.

The reversing switch is provided with a flanged wheel for carrying the operating rope. This switch is so arranged that there is a wide angle in the off position so as to minimize the probability of inadvertently throwing over to the reverse position when trying to stop. A notching device holds the switch in the off position until purposely moved by the operator. The motor *cannot* be reversed without first cutting the starting resistance into the circuit.
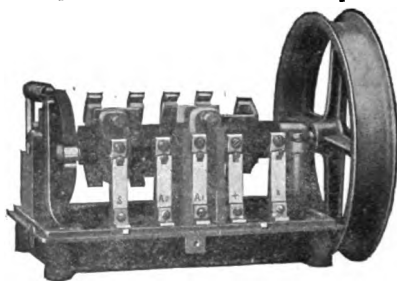
SAFETY DEVICES

REVERSING SWITCH WITH COVER REMOVED

In all elevator installations certain safety devices must be used to prevent accidents. To guard against over-travel of the car in either direction, stop motion or limit switches are necessary; and to keep the cable from unwinding from the hoist drum in case the car catches, a slack cable switch is installed. Limit switches can be installed in the hatchway or shaft, so as to be tripped by the car at the ends of its travel or

they can be geared to the elevator drum shaft. They are not depended on to cause the regular stops at the top and bottom floors, but are brought into action only when the car is allowed to move past these floors. Since the limit switch opens only the control circuit of the magnet switches, it is never required to break more than a very small current, and in normal service, with an occasional inspection and oiling when the other parts of the elevator are inspected, will last almost indefinitely. The same statement applies also to the slack cable switch, which is very seldom called into ac-
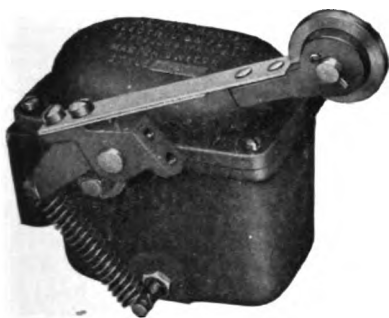
HATCHWAY LIMIT SWITCH

tion. The hatchway limit switch, which is a single-pole, double-break snap switch, operates when the car passes its stopping point by depressing an arm; a spring closes the switch automatically as soon as the pressure is removed from the arm. The switch parts are enclosed in a cast iron box from which they are easily removed. One of these switches is installed at the bottom of the elevator shaft and one at the top. If preferred, these switches may be arranged so that if opened the operator is put to the trouble of resetting the switch before he can again start the elevator.

The *geared* switch for limiting the car travel is a master
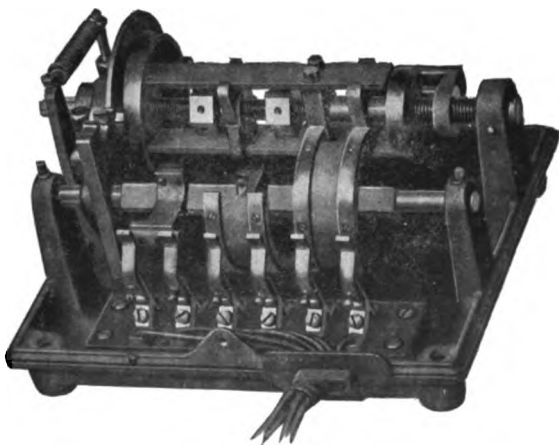
GEARED LIMIT SWITCH WITH COVER REMOVED

switch operated automatically by a traveling screw which is positively driven from the drum shaft. Near the end of the car travel in either direction this limit switch first reduces the speed, if two-speed control is used, and then stops the car, exactly as would be done with the master switch in the car. The operator

can then move the car only in the reverse direction. This geared limit switch can be arranged for any set of conditions that require a piece of apparatus to travel within assigned limits.

The use of two hatchway limit switches or of one geared limit switch will make a safe installation so far as limiting the car travel is concerned, but for the best possible insurance against accident the use of all three is recommended.

The slack cable switch is an automatically operated master switch which stops the motor in case the rope slackens from any cause, such as breakage or catching of the car. The switch is mounted on one side of the winding drum and a little below it, and is operated by means of two bars that extend across the
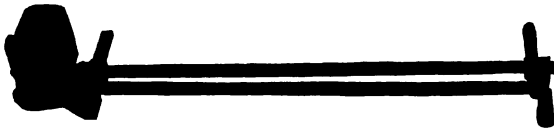
SLACK CABLE SWITCH

drum. The slack rope presses against the cross bar and trips the switch, thus opening the control circuit, releasing the magnet switches and stopping the motor and the car. The switch cannot be reset until the cable has been replaced on the drum; an inspection of the drum and the necssary repairs are thereby assured.

METER AND RELAY CONNECTIONS (Cont.)

THREE-PHASE-FOUR-WIRE CIRCUITS

HAROLD W. BROWN

THREE-PHASE—four-wire circuits require different connections from those for three-phase—three-wire circuits, because the current returns in part through the neutral instead of flowing entirely in the other three lines. This affects the relation of currents in the three lines, so that the assumptions ordinarily made regarding three-wire circuits are not always true. On this account the grouping of meters and transformers is different, and in some cases more meters and transformers are required than for three-wire circuits.
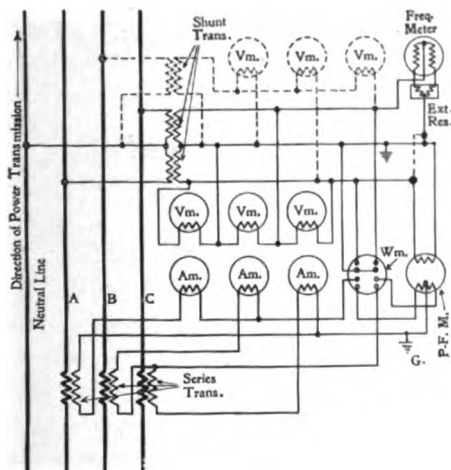
FIG. I—GROUP OF METERS CONNECTED TO THREE-PHASE, FOUR-WIRE CIRCUIT

Without the use of voltmeter or ammeter receptacles.

GROUPING

Fig. 1 represents a group of meters, connected to two shunt and three series transformers on a three-phase—four-wire circuit. The series transformers are delta-connected, but each of the three ammeters is connected in series with a single transformer, thus measuring the current on a single line. The wattmeter and power-factor meter are connected to the delta-connected series transformers in such way that, with a current of five amperes in each transformer, a current of 8.66 amperes flows in each current circuit of these meters.*

Two shunt transformers, represented by full lines in Fig. 1, are V-connected to the neutral line. The voltage circuits of the wattmeter are connected, by means of these transformers, from

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*See Fig. 1 (a) and (a'), and Table I in the JOURNAL for December, 1908, Vol V., pp. 725-6, for vector diagram and diagram of connections of delta-connected series transformers and table of current ratios and phase relations.

two of the lines to neutral. The voltage circuit of the power-factor meter is connected from one line to neutral. Two voltmeters are connected each from one line to neutral; the other voltmeter is connected between two lines, neither of which is neutral. If it is desired to measure the e. m. f. from *each* line to neutral, or between each two lines, another shunt transformer must be added, as represented by dotted lines. The three voltmeters shown dotted, together with the other three voltmeters, will give any desired measurement of voltage. A frequency meter is shown on one of the shunt transformers. It may be connected across two transformers as shown by the dotted lines, instead of one, if it is desired to increase its e. m. f. The connections of the wattmeter and power-factor meter shown here are discussed separately with reference to Figs. 3 and 6.

Fig. 2 is a diagram of connections similar to Fig. 1, in which a single voltmeter and ammeter are connected to contact devices to measure the various e. m. f.'s and currents. There are three Y-connected

FIG. 2—GROUP OF METERS CONNECTED TO THREE-PHASE, FOUR-WIRE CIRCUIT

With contact devices for switching the voltmeter and ammeter to the various lines.

shunt transformers, and the voltmeter may be connected by means of the two dial switches, from any one of the four lines to any other. If connection is made to the upper point on the left hand dial and to any point on the right hand dial, the e. m. f. indicated is that from one of the lines to neutral. Otherwise the measurement is that of the e. m. f. between two lines neither of which is neutral. Each of the dials, as shown, has points for connecting to three of the four lines. Sometimes each dial has four points instead of three, permitting connection on either dial to any line; but this extra point is not necessary. The ammeter measures the current in any one of the lines *A*, *B* or *C*, when the plug is in the corresponding receptacle. A delta con-

nection of series transformers is required for the wattmeter, and the current in the neutral line cannot be measured in this case, but if the transformers were Y-connected, as in Fig. 8, the ammeter could be made to measure also the current in neutral. The frequency meter may be connected between *C* and *B*, as indicated by the full lines, or between *C* and neutral, as indicated by the dotted line. The e. m. f. on the frequency meter in the latter case is only 0.58 of that in the former.

WATTMETER AND POWER-FACTOR METER

These meters are not primarily intended for use on three-phase—four-wire circuits, so that the current with delta-connected series transformers is 1.732 times as large as the normal current* on a three-wire circuit, and the meter therefore is more liable to heat excessively in case of overload where it is connected to a three-phase — four-wire circuit, if ordinary transformers are used. The shunt transformers, being V-connected to neutral, have an e. m. f. of only 1/1.732 of the e. m. f. between non-neutral lines, so that what is gained because of the larger current is lost through reduced e. m. f. (unless the shunt transformers are different from those used on similar three-wire circuits). Both the current and the e. m. f. of the meter are shifted through a phase angle of 30 degrees, so that the phase relation between current and e. m. f. remains unchanged from that of a three-wire circuit.
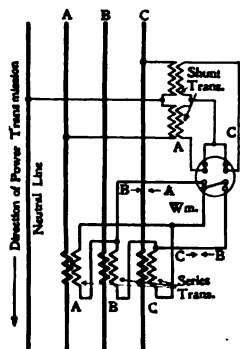
FIG. 3—POLYPHASE WATTMETER CONNECTIONS

Wattmeter—A polyphase wattmeter is shown connected to a three-phase—four-wire circuit, in Fig. 3. This method of connecting gives a correct measurement of power with any condition of balanced or unbalanced current. An inequality of e. m. f.'s would introduce a slight theoretical error, but with any ordinary inequality the error is altogether negligible. The correctness of this method of measurement may be seen from the following: The current from transformer *A*, Fig. 3, passes through the left hand current circuit of the wattmeter and reacts with the e. m. f. between *A* and neutral, thus measuring the power transmitted over line *A*. Similarly, the current in transformer *C* reacts with

See footnote, page 112.

the e. m. f. between C and neutral, measuring the power transmitted by line C. The current in B passes in the negative direction (as shown by the lettered arrows) through both the right and left hand current circuits, thus reacting with the e. m. f.'s on both sides of the meter. This is equivalent to reacting with the resultant of the two e. m. f.'s. If the e. m. f.'s from the three lines to neutral are equal, and the angle of phase difference is 120 degrees in each case, the e. m. f. from B to neutral is the same as the resultant of the two e. m. f.'s from A and C to neutral. It is in phase with this resultant, but in the opposite direction, so that if the current in B reacts with these two e. m. f.'s in a negative direction, the result is the same as if it were with the e. m. f. from B to neutral. Thus, the sum of the power transmitted by all the lines is measured by the wattmeter.

FIG. 4—THREE SINGLE-PHASE WATTMETERS OR POWER-FACTOR METERS
The power or power-factor is indicated on the three lines, separately.

Three single-phase wattmeters may be connected as in Fig. 4 to indicate separately the power transmitted by the three lines, A, B and C. Both the shunt and series transformers are Y-connected so that each wattmeter receives the current of the series transformer on one line, and the e. m. f. from that line to neutral.

If the single-phase wattmeters shown in Fig. 4 all have the same resistance and reactance in their voltage windings, their voltage circuits may be Y-connected to *two* transformers as in Fig. 5 (instead of three, as in Fig. 4). An artificial neutral is

FIG. 5—SIMILAR TO FIG. 4, EXCEPT THAT THE SHUNT TRANSFORMERS ARE Y-CONNECTED
An artificial neutral is thus obtained, using but two transformers.

produced, and each voltage circuit connects from its line to neutral. An error is introduced if, as a result of unbalancing, the

voltages from lines *A, B* and *C* to the neutral line are not equal; this error will ordinarily be very small, however, because the un- balancing of e. m. f.'s is small as compared with the unbalancing of current, and will therefore be neg- ligible.

Power-Factor Meter—Two power- factor meters are shown in Fig. 6, in which No. 1 is connected to conform with standard diagrams, and will give the right indication with one sequence of phases in the primary circuit, but if the sequence is reversed it will give a wrong indication. The test, as on a three-wire circuit, is to disconnect the voltage cir- cuit and observe the direction of rota- tion. If with the connections of No. 1 the pointer rotates in the clockwise di- rection the meter will indicate correctly, but if in the counter-clockwise direction, the connections must be changed. The simplest way is to interchange the left* and middle series connections, and to in- terchange the voltage connections. The

FIG. 6—POLYPHASE POWER-FACTOR METER CONNEC-TIONS

The connections for met- er *No. 1* are the same as for the power-factor meter in Fig. 1. If the pointer ro- tates in the "lag" direction the meter should be con- nected as *No. 2.*

power-factor meter will then be connected as No. 2. The change in phase relations that takes place in changing from No. 1 to No. 2 is illustrated in Fig. 7. The currents in the three series transformers are *OA, OB* and *OC*. The combinations of these currents flowing in at the left, middle and right hand current terminals of the power-
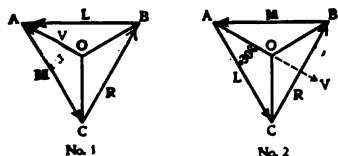
FIG. 7—VECTOR DIAGRAMS SHOW-ING RELATIONS OF CURRENT AND E.M.F. IN POWER-FACTOR METERS CONNECTED AS IN FIG. 6

factor meter are represented by *L, M and R*, respectfplly. The e. m. f. is represented by *V*. As was shown with respect to three-phase—three-wire connections† the e. m. f. is 30 degrees out of phase with *L*, and 90 degrees out of phase with *R*. This is the case with both No. 1 and No. 2, but the direction of phase difference is opposite in No. 2 to that in No. 1; that iss, if *V* lags behind *L* in No. 1, it leads in No2 and vice versa.

*As viewed from the rear.

†See the JOURNAL for December, 1908, Vol. V., p. 730.

Three single-phase power-factor meters may be connected as in Figs. 4 and 5 to indicate the power-factor of each line separately. The sequence of phases is not involved in these connections. The voltage circuits of the three meters in Fig. 5 must all have equal resistances and reactances in order that the common point shall be a true neutral point and that each meter shall indicate the true power-factor.

VOLTMETERS AND AMMETERS

The ammeter in Fig. 8 may be connected by means of the ammeter receptacles into any one of the three separate leads of the Y-connected transformers, or into the lead to the common connection. In the latter case the ammeter measures the current in the neutral line; in the former, the current in one of the other lines.
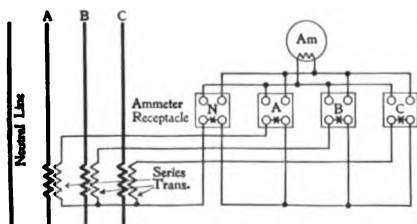
FIG. 8 — AMMETER AND THREE SERIES TRANSFORMERS, CONNECTED TO MEASURE THE CURRENT IN ANY LINE.

With this three-phase—four-wire connection, the current in the secondary return circuit is proportional to the current in the primary neutral line.

The voltmeter, ammeter and voltage compensator in Fig. 9 are connected by means of dial contacts and ammeter receptacles to measure the current in any line (including neutral), the e. m. f. between any two lines at a distant point, or the line drop in any one or two lines between the meter transformers and the distant point. Each of the shunt transformer leads, *A, B. C* and *N*, connects to corresponding points on each of two dials. Any one of these points may be connected to the middle of the dial, and from there to one of the voltmeter terminals. The line from the left hand dial connects to the left hand voltmeter terminal through the voltage compensator, so that the voltage indication is affected by whatever current flows through the current circuit of the compensator. Around each of these dials are four ammeter receptacles, each in series with a series transformer on one of the lines. The connections to the four left hand receptacles are so made that when a plug is inserted therein, the ammeter and the current coil of the compensator will receive current. The current from any one of the four left hand receptacles may be deflected through the ammeter, and thence through the compensator. The current from a right

hand receptacle flows through the compensator only. Thus, the ammeter current is controlled by the position of the left hand plug, but the current in the compensator depends upon the position of both plugs.

If the voltmeter is connected between two lines—for example, *A* on the left hand dial and *B* on the right, and no plugs are inserted in the ammeter receptacles, the voltage between *A* and *B* is indicated without compensation; but if the plugs are inserted at *A* on the left, and *B* on the right, the voltage is com-
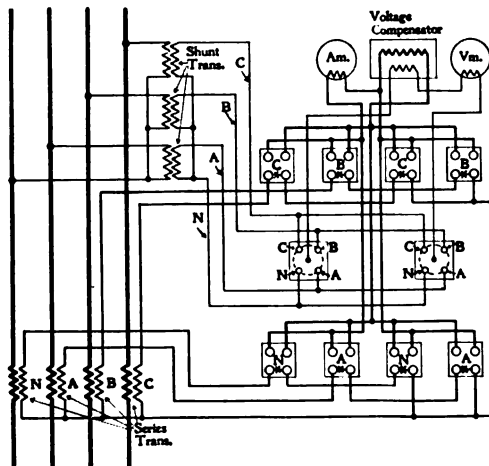
FIG. 9—VOLTMETER, AMMETER AND VOLTAGE COM-
PENSATOR CONNECTED TO THREE-PHASE—FOUR-
WIRE CIRCUIT THROUGH RECEPTACLES AND DIAL
SWITCHES
For measuring current in any line, e.m.f. between any two lines, e.m.f. compensated for line drop, or line drop independent of e.m.f.

pensated for the drop in *A* and *B*, and the ammeter reads the current in *A*.

If the voltmeter is connected to *A* both on the right and the left hand dials it indicates zero, but if an ammeter plug is then inserted at *A* on either the right or the left, but not on both sides, the line drop in *A* is indicated by means of the compensator. With this voltmeter connection, if a plug is inserted at *A* on the left and *B* on the right, the voltmeter measures the resultant of the drop in lines *A* and *B*. Similar measurements can be made in the same way on the other lines. The neutral line is to be treated as any other line in making these measurements.

It should be noted that, with the proper adjustments, the

compensator makes the correction of e. m. f. for line drop *in phase* with the actual drop. This is true at any power-factor, with either balanced or unbalanced load. Thus, when the compensator is brought into service, the voltmeter indicates the correct e. m. f. at a distant point, whatever the nature of the load on the line.

GENERAL CONCLUSIONS

The minimum number of meters and meter transformers, for a three-phase—four-wire circuit, is always as great, and sometimes greater, than is required for a three-wire circuit. One single-phase wattmeter or power-factor meter is not suitable for the entire circuit, because a four-wire circuit is usually unbalanced, and the unbalancing would affect the accuracy of these instruments. Three series transformers are required on four-wire circuits for use with wattmeters, power-factor meters, or ammeters, if measurements are to be made on all the phases. Three shunt transformers must be provided if it is required to measure the e. m. f. from each line to neutral and also between any two non-neutral (main) lines. Three shunt transformers are required (whether the e. m. f.'s to neutral are to be measured or not) if a wattmeter is also to be used in addition to the voltmeters measuring the e. m. f.'s between all the non-neutral lines. If the e. m. f.'s from only one or two lines to neutral and the e. m. f. between only one pair of main lines is required, only two shunt transformers are necessary for both voltmeter and wattmeter.

A grounded neutral system must be treated as a four-wire circuit, because, if any current returns through the ground, the currents in the other lines would be the same as if it were returning through a neutral line. Sometimes a system is grounded or has a neutral line in one part of the circuit, but has no connection to ground or neutral in another part. At all points between the connections to ground or neutral, the system must be considered as a four-wire circuit, but at other points connections may be made for either a three-wire or a four-wire circuit. A common arrangement of this kind is to have one side of the power transformers delta-connected, and the other side Y-connected. Three lines are brought out from the delta-connection, and four from the Y-connection. In Fig. 10 the middle portion is a four-wire circuit having Y-connected power transformers with a neutral line brought out from the common transformer

connection. This part must be treated as a four-wire circuit. The left hand part is delta-connected, and the right hand part has no connection to neutral. Both the left and right hand parts may therefore be considered as three-wire circuits.

The method of connecting two wattmeters to have equal readings on a balanced three-phase circuit, is not strictly accurate on an unbalanced four-wire circuit, when there is any current
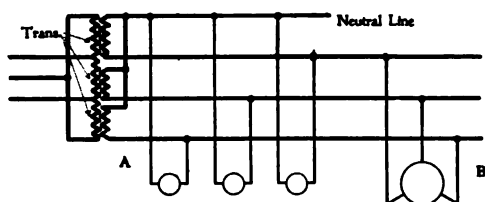
FIG. 10—CONNECTIONS REPRESENTING PARTLY
THREE-WIRE AND PARTLY FOUR-WIRE CIRCUIT

A represents any single-phase or three-phase apparatus connected to neutral, while the apparatus at *B* has no neutral connection.

flowing in the neutral line;* but this error is not likely to be large.

Protective relays are usually made to protect the lines whether a ground occurs or not, so that ordinarily the connections for a grounded neutral three-phase system are the same as for one that is not grounded.

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*This method of connection was described in the JOURNAL for January, 1909, Vol. VI., pp. 48-49.

EXPERIENCE ON THE ROAD

OIL ON THE COMMUTATOR

LEONARD WORK

A DIRECT-CURRENT generator had been operating satisfactorily on light load. Upon increasing the load to the normal rated capacity, moderate sparking at the brushes began. The commutator was trued up and the brushes readjusted, whereupon the sparking ceased, but only to reappear after a few days. This time there was considerable sparking not only at the brushes, but also, at brief intervals, at various spots between some of the bars of the commutator. At these points the insulation was rapidly being destroyed and threatening ultimate serious damage to the machine.

Careful inspection revealed nothing except a thin greasy film on the commutator and a similar condition of the contact surfaces of the brushes. This was easily removed, but in a few hours it had reappeared, and with it, renewed sparking. The cause of the sparking was now apparent but the source of the troublesome film was still a mystery. Positively no oil was thrown upon the commutator from either the engine or bearings. The operator insisted that he had not used any oil on the affected parts for some months.

Moreover, minute examination of the brushes disclosed no trace of oil. A suggestion that they might contain this substance from former applications was thought absurd. Nevertheless, it was decided to make sure on this point. The brushes were removed and heated in the flame of a gas stove. In a few minutes there was no doubt as to the source of the commutator troubles. The amount of oil or grease that began to fry out of those innocent looking carbon brushes was astonishing. The frying process was continued until the brushes stopped smoking. They were then allowed to cool and were readjusted in the holders.

The damaged spots between the bars were cleaned out and filled up and the generator was started and given its full load. Soon the commutator took on a clean dark glaze and has since run absolutely sparkless and without further trouble from this source.

THE JOURNAL QUESTION BOX

205—COPPER LOSS IN CONVERTERS— How is the copper loss in a rotary converter armature calculated, taking into account the equivalent currents in the armature winding? Should it be calculated from the resistance of the alternating-current or the direct-current side of the machine?   J. W. R.

This is explained in an article on "Rotary Converters" by Mr. R. E. Workman in the series on "Factory Testing of Electrical Machinery," Vol. II., March, 1905, p. 181. The copper loss for a three-phase rotary converter at one hundred percent power-factor is 56 percent of the copper loss of the machine operating as a direct-current generator; that of a two-phase converter, 39 percent, that of a six-phase converter 26 percent. See also No. 57 in the May issue, and Na. 156 in the October issue.   F. D. N.

206—TRANSMISSION LINE CALCULATIONS—Please give a formula for calculating the line voltage E of a transmission system when the voltage e, at the receiving end is given; the impedance drop c over the line; the resultant power-factor of the line and load, or its corresponding angle, and the power-factor of the line alone, or its corresponding angle. In computing the impedance of a transmission line, the capacity $1 \div 2 n$ fC seems to be so large, in usual cases, as to render the resistance and inductance almost negligible, the factor C in the expression for capacity being of the order 10^{-8} farad. I cannot reconcile this with statements I have read to the effect that, in computing trans-

mission line regulation, the line capacity is often unimportant and negligible. I would be pleased to learn where I am in error.   A. H. F.

To calculate the value of E, the values of e, c and the power-factor of both load and line must be known. These values of power-factor can be calculated if the effective resistance, r, and the reactance, x, of line and load are given, from the formula, $P\text{-}F = r \div \sqrt{r^2 + x^2}$. The reactance, x is made up of inductance and capacity. Assuming the power-factors p and p_1 for the load and line respectively, the reactive factors are q (which equals $\sqrt{1 - p^2}$), and q_1 (which equals $\sqrt{1 - p^2_1}$). Then E is the vector sum of the power and reactive components of e and c respectively.

Power component $= ep + cp_1$.

Reactive component $= eq + cq_1$.

$$E = \sqrt{(ep + cp_1)^2 + (eq + cq_1)^2}.$$

The power-factor of the whole system is, then, $(ep + cp_1) \div E$. Regarding the factor $1 \div 2 \pi$ fC, it is probable that, in using this in the formula, you have assumed that the capacity is in series with the resistance and inductance. As a matter of fact, as the capacity is distributed over the line, it is partly in series and partly in parallel. Calculations for the average transmission line do not require such a high degree of accuracy and the capacity may be assumed as concentrated at intervals along the line instead of being uniformly distributed. In many cases the capacity has so little effect that it is negligible.   A. W. C.

207—RE-CONNECTING INDUCTION MOTOR—If a three-phase, six-pole induction motor connected in two-circuit delta were connected in four-circuit Y would

there be any difference in the operation of the motor? If so, please give the reason.

H. P. W.

If a three-phase induction motor is to be re-connected for any other voltage than that for which it was designed and the same performances are desired, the ampere-turns per phase should be kept the same, *i. e.,* the number of turns per phase should be changed in the same ratio as the voltage per phase. Therefore, if the motor was originally connected in four-circuit star and re-connected in two-circuit delta, the turns per phase are doubled; the voltage, however, is increased only $\sqrt{3}$ times the phase voltage of the star connection, *i. e.,* if assumed that the line voltage remains the same. Therefore, it is evident that the maximum torque of the motors will be 33 percent less, and the copper loss in the primary as well as in the secondary will be increased 33 percent. Hence, if the same performance is required, the voltage should be raised 15 percent. On the other hand, it should not be overlooked that with ordinary windings, a three-phase, six-pole motor cannot be connected in four parallel circuits.

H. C. S.

208—IN TRANSMISSION LINE CAL-CULATIONS is the line capacity assumed to be in series with the line inductance or in parallel? (b) Is the capacity of a piece of apparatus, such as a synchronous motor, in series or in parallel with its inductance? (c) What relation does the charging current of the line hold to the total current? Is it part of the wattless component, viz., I sin Θ? Please show the relations by a vector diagram. (d) If a transmission system consists of a bank of transformers (step-up), a transmission line, a bank of step-down transformers and a synchronous motor, how should the total impedance be calculated? Would the separate impedances be calculated separately and added in series or in parallel?

H. G. H.

(a) The line electrostatic capacity as measured is generally assumed to be in series with one-half of the line. This is a very approximate assumption; a more exact assumption would be that the total capacity is distributed throughout the length of the transmission line; it would thus be partly in parallel and partly in series. This factor is sometimes so small that it is entirely negligible; where it is an appreciable factor the method given above is sufficiently accurate. (b) The capacity of a synchronous motor is in parallel with its inductance. (c) Charging current is at right angles to the e.m.f., and if the load is non-inductive, is at right angles to the main current. If the load is inductive the charging current is not necessarily at right angles to the total current. The relations of the e.m.f., main current and charging current are shown in Fig. 208 (a) for a condition of inductive load, *I'* representing the charging current, *E* representing e.m.f. and *I* representing the total current. (d)
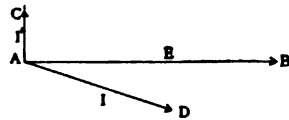
FIG. 208 (a)

To obtain the total impedance of the circuit, the impedances of the respective parts of the circuit should be calculated separately and added in series as the parts are connected. The impedance of the secondary of the transformer is of course expressed in terms of the primary by multiplying or dividing the calculated secondary impedance by the ratio of transformation, according to whether the transformer is a lowering or raising transformer.

A. W. C.

209—OSCILLOGRAPH IN SHOE TEST-ING—Could an oscillograph such as described in the article on "The Oscillograph on the Test Floor" in the JOURNAL for July, 1908, be constructed without a great deal of difficulty? Having read this article, it has seemed that such an outfit would be of great value to us in connection with our power house and transmission line work. The construction

of the moving mirrors has appeared to be a very formidable job for one not accustomed to such work.   A. D. M.

The instrument described in the above article is the Dudell Oscillograph and is made by the Cambridge Scientific Instrument Co., Cambridge, England, there being an agency in Philadelphia which handles their products. Through this source it is possible to obtain the oscillograph mirrors, at about $1.00 apiece, and also the delicate flat phosphor-bronze suspension wire which is required in the construction of the movable element. It is necessary to operate the oscillograph in a transparent damping oil, for which purpose an oil-tight vessel is required. A steady-burning arc lamp with hand feed, giving an intense light, must also be provided. Electro-magnets excited from a battery or other source of direct-current may be used instead of the permanent magnets. An arrangement of lenses and an adjustable aperture are required to control the beam of light from the arc lamp which is thrown on the mirrors of the respective elements of the oscillograph and reflected by them. The oscillograph has to be mounted inside a "dark box." When the oscillograph is used on high-voltage circuits a non-inductive resistance is usually required, to cut down the current through the oscillograph element to a value of approximately 0.1 ampere; such a resistance is difficult to make. An oscillograph having two or more elements requires a means of adjusting the positions of the mirrors for simultaneous readings. Very accurate work is required in constructing the movable elements and these adjustments, hence it would not be practicable for any but an expert instrument maker to attempt to construct an oscillograph having more than one element. It would be difficult to obtain an instrument having a degree of sensitiveness greater than one-fiftieth second. Such a single-element instrument would, nevertheless, be very serviceable in power house work.   H. H. G.

210—Two-Phase vs. Three-Phase—What are the relative advantages of two and three-phase systems? Will the tendency toward three-phase standardization eventually make two-phase apparatus, especially motors, obsolete? If so, would you say that it would be advisable to begin now to buy three-phase motors and generators for any considerable immediate extensions, such, for example, as increasing a mill installation of thirty 50-hp. motors to fifty 50-hp. motors; this increase in the number of motors to be accompanied by a corresponding increase in generator capacity. The cost of copper wire required to finish wiring the entire plant would not exceed $7 000,00, so that any percentage of saving in copper would be figured on this basis.   W. P. F.

Two-phase systems are commonly employed where it is found more convenient to balance, for example, a simple lighting load on two circuits rather than three. In the use of three-phase circuits there is, of course, a considerable saving in copper and herein lies one of its chief advantages. In other words, each system has its own advantages for various applications. Insofar as the motors themselves are concerned there is no appreciable advantage insofar as design or operation are concerned in one over the other. Regarding the extension of the system in question, it would not seem practicable to undergo the expense of equipping for two-phase, four-wire distribution where a three-phase system would be entirely satisfactory and would, in addition, give a corresponding saving in expense for copper.   P. M. L.

211—Repairing Short-Circuit on Generator—In a large six-pole generator the commutator has 178 bars, the armature is series-wound, and between bars No. 178 and No. 1, there is a short circuit and in order to make a cheap repair I have been asked to cut out the coils between these bars. This I propose to do in the following manner: To connect the top

lead of the coil in bar No. 1 to bar No. 2, and to connect the bottom lead in bar No. 1 and bar No. 178 together. If you know of any better way than this without re-insulating between these bars, please explain the same to me; also, please explain the objection to the plan proposed above.

H. P. W.

One coil may be eliminated as follows: Disconnect the lower lead in bar No. 1 or the top lead in bar No. 178; tape up the bare end of the lead and secure it so that it will not give trouble. Bars 1 and 2 should be either connected or soldered together. A schemetic diagram of the series-wound armature will make it apparent that this method of connection simply eliminats one coil by open-circuiting it at one of its terminals. The commutator bar is electrically connected to the adjacent bar because a dead bar would very probably cause sparking due to the gap introduced into the commutator. If one terminal of the coil to be eliminated were not disconnected from the commutator this coil would be short-circuited by the short-circuit between the two commutator bars and the current in this coil would be liable to cause excessive local heating.

C. F. L.

212—SINGLE-PHASE LOADS ON THREE-PHASE ALTERNATORS— When a single-phase railway system is supplied with power by a three-phase generator, one phase being grounded and the other two phases being sent out on the trolley in different directions, what is the division of load between the phases of the generator, assuming the two phases to be loaded equally, with a star-connected generator and also with a delta-connected generator? What is the effect of unbalancing of the load on the two phases?

P. C. D.

We have no knowledge of such an arrangement of circuits as you suggest ever having been used in practice. The ordinary method is to operate the single-phase railway circuit through one phase of the generator in case a three-phase machine is used. This does not prevent the use of a small motor and lighting load on the generator. In railway operation a Tirrill regulator is very commonly used to maintain constant voltage on that phase of the generator supplying single-phase power to the railway circuit. The arrangement of the iron in the armature and fields, the type of generator employed for this service and the arrangement of armature coils is so designed that unbalanced loads do not have a serious effect on the operation of the machine.

F. E. W.

213—POWER-FACTOR—Please explain why an unloaded transformer has a low power-factor, and how the power-factor is improved when the transformer is loaded.

F. H. C.

In an unloaded transformer the total amount of power drawn from the line is that required to magnetize the iron, plus a small copper loss. The magnetizing current is nearly 90 degrees out of phase with the e.m.f. When the transformer is loaded the magnetizing component is then only a small percent of the total power. The real or power component of the current is in phase with the e.m.f. and the total current would be in phase were it not for the effect of the "wattless" or 90-degree component.

A. D. F.

214—TORQUE—How does the rotating magnetic field in the stator of an induction motor pull the short-circuited secondary of the motor around and produce rotation? Explain for two and three-phase. What is the action causing the disc to turn in an alternating-current ammeter? In the old types of overload relays having aluminum vanes, what is the action that pulls the vanes into the magnetic circuit?

F. H. C.

The torque in an induction motor is produced by magnetic attraction between the primary and secondary fields. The rotating primary magnetic field is the resultant of the alternating fields set up by the currents in the respective phases of the primary circuit, whether two-phase or three-phase. The secondary mag-

netic field is the resultant of currents induced in the secondary winding by the primary currents through magnetic induction (commonly termed "transformer action"). In the single-phase motor the resultant rotating field for starting is usually obtained by means of an auxiliary winding which is automatically cut out after the motor reaches full speed. The single-phase motor is similar to the two-phase motor in its principle of operation except that the second phase (supplying the alternating field which interacts with the primary alternating field produced by the single-phase current in the primary circuit, to produce the rotating field) is induced through transformer action between the primary and secondary magnetic circuits. (This is explained in Nos. 8 and 180 in the January and December, 1908, issues respectively.) In meters and relays using magnetic vanes for the moving elements, the torque is produced in a similar manner through the magnetic attraction between the current in the coils and induced eddy currents in the vanes.

215—Relation Between Iron Loss and Frequency—Please explain the statement: "The higher the frequency the less the iron loss," i. e., why should the iron losses in a 60-cycle transformer decrease when used on a 133-cycle circuit? **G. S.**

The induction or magnetic density of the magnetic circuit varies inversely as the frequency. The iron loss of the transformer is the sum of the losses due to eddy currents in the laminations and the losses due to hysteresis. The eddy current losses vary directly as the square of the frequency and also as the square of the magnetic density. Therefore, as the induction is lowered in proportion to the increase in frequency, these two factors cancel each other and the eddy currents losses remains the same. The hysteresis loss, however, has been proved, both by test and the eddy current losses remain as the frequency, and approximately as the 1.6 power of the magnetic density. Therefore, as the magnetic density (induction) varies inversely as the frequency, the hysteresis loss

varies as the 0.6 power of the frequency. Thus, in an ordinary 60-cycle transformer operating at 133 cycles, the iron loss would be approximately 75 percent of that at no-cycles. **A. D. F.**

216—Referring to No. 100, in the July, 1908, issue in which is shown a lap-wound armature with 87 commutator segments, does not this winding practically necessitate the use of cross-connections and, accordingly, the method indicated in which odd bars are used? **A. W. R.**

It is not absolutely necessary to use cross-connections on a lap-wound armature; in fact, cross-connections are of no use where the field strength per pole is uniform, where the poles and brushes are accurately spaced (there being as many brushes or groups of brushes as there are poles) and where the armature is concentric with the bore of the poles. However, cross-connections could be applied to the armature in question without involving idle coils or bars, since it is not necessary to cross-connect for every bar. Eleven cross-connections would be sufficient and could be worked in without difficulty, the connecting being done as if there were 88 bars. It will be noted that each bar is diametrically opposite a segment of insulation so that each cross-connection will be one-half bar out of the true position. This, however, would not prove unsatisfactory on an 87-bar commutator. **F. A. R.**

217—Auto-Transformers vs. Regular Transformers — What are the advantages and disadvantages of three-phase auto-transformers, Y-connected, in comparison with a regular two-coil, two-to-one transformer, in transforming from 10 000 to 20 000 volts? **E. H. B.**

The main advantage is that, for a given rated capacity of apparatus, twice as much total power can be handled with an auto-transformer outfit as with a regular transformer. In general, the main disadvantage in the use of auto-transformers to obtain low-tension power from high-tension circuits is that there is a

greater liability to accident, due to the fact that the higher voltage is not entirely eliminated from the low-tension side of the circuit as is the case with regular transformers having separate primary and secondary windings. For explanation of saving in capacity see No. 6 in the January, 1908, issue, also No. 98, July, 1908, and No. 198, November, 1908.   E. C. S.

218—NON-MAGNETIC WATCHES—Is it necessary, in carrying a watch around electrical machinery, that it should be non-magnetic in order not to be affected by the stray fields? A leading local jeweler claims that it is not especially necessary to use a non-magnetic watch around alternating-current machines. Will you please give the facts regarding this matter and also state the best make of non-magnetic watch? In case a watch has been so affected, how may it best be demagnetized?   D. R.

Trouble caused by stray magnetic fields from electrical machines and from heavy currents flowing in bus-bars and conductors is primarily the result of the effect of the fields in magnetizing the steel hair spring of the watch. An attempt has been made to construct an accurate and satisfactory watch with a hair spring made of some para-magnetic material. It is quite generally concededed, however, that all attempts thus far have been a practical failure as steel appears to be the only reliable material for hair springs. It has been found that an annealed sheet iron case will protect the watch to some extent but will not make it proof against the effects of strong fields such as are present in the immediate vicinity of bus-bars, etc., carrying heavy current and the leakage fields around both alternating-current and direct-current machines. As the fields of both' types of machines are excited by direct-current there is no less danger in this respect from the effect of one than of the other. Alternating-current bus-bars, of course, would not have an injurious effect on a watch. In alternators of the revolving field type, cases have been noted where the leakage field at the end of the shaft was sufficient to seriously affect a watch. A person entering a power house merely to pay a casual visit and not getting into close proximity with any of the machines would, of course, not be liable to have his watch affected, but on the other hand, power house attendants are liable to meet with trouble from this source and in this case an annealed iron case such as noted above is a valuable, although not absolute, protection. To demagnetize a watch so affected, mount it in a revolvable frame in front of one pole of a powerful electro-magnet arranged to be excited with direct-current. Revolve the watch at high speed and then turn on the current gradually. After ten or fifteen seconds turn the current off gradually and take the watch out of the frame. If alternating-current is available the watch need not be revolved but may be held sationary in front of the magnet pole and then slowly removed. In this case the magnet should have a laminated core. J. C. F.

219—METERING CONVENTIONS — Do the directions given regarding wattmeters, in the article on "Meter and Relay Connections" in the JOURNAL for May, 1908, Vol. V., p. 262, refer to the binding posts or the windings of the coils, i. e., would one have to trace the direction of coil winding, or is it standard practice to so arrange the terminals of the coils that the position of the binding posts is a sufficient guide?   C. G. B.

The arrangement of binding posts is different with different kinds of wattmeters, but in general the relations of external connections in corresponding current and voltage circuits are those given in the article referred to. Some makes of meters have the voltage binding posts at the bottom, and current at the top, and others have the current binding posts on the side, adjacent to the voltage binding posts. An inspection of the meter, however, usually shows the right relationship. As noted in the introduction, the diagrams given in the series of particles referred to are made to conform with Westinghouse switchboard meters.   H. W. B.

Notes on Illumination

The sixteen candle-power incandescent lamp has played a unique part in the development of the electrical industry. It has been a useful light giver, sometimes the equivalent of sixteen tallow dips, and sometimes less. It has also been a convenient unit which has solved in a simple way many modern problems of electrical rating and of illuminating engineering. For example, the rating of an alternator now involves k. v. a. and kw, power-factor, regulation, temperature and other things, whereas, in the early days a machine had a capacity of "650 lights" or "1300 lights," without further complication. In fact, an old dynamo was offered at a sacrifice sale in North Carolina a few months ago as a "300 liter." The problem in illumination was simply to find the number of lamps (which was usually fixed by the number of gas jets to be replaced) without consideration of such new factors as candle-feet, distribution curves, intensifying reflectors, color values or even illuminating engineers.

Most of us understand pretty well why the 16 c-p. unit is no longer adequate for designating dynamos, transformers, meters and wire tables, but we do not see so clearly why it has had to give place to so many new factors. The advent of new lamps is mainly responsible for destroying the domination of the 16 c-p. unit. The term "16 c-p." no longer stands for 56 watts, more or less; in fact, instead of rating dynamos by their lamp capacity, we now even rate tungsten lamps in watts. The number "16" has lost its importance, as Nernst, Cooper Hewitt, Moore and, with few exceptions, tungsten lamps are not made in 16 c-p. units. Then again, even "c-p" has lost its simplicity because the Nernst lamp gives hemispherical rather than spherical illumination.

But, aside from all these physical elements, the large factor, and the one which makes this branch of electrical engineering different from others is that illumination is primarily physiological. The new sources of light, of greatly increased illuminating power, of increased intrinsic brilliancy, of different shapes and of different color values have a different effect, not only on the wattmeter, but also on the eye. The passing of the 16 c-p. carbon filament lamp

from its controlling position has brought the physiological phase of illumination to the front. The basic principles underlying the new science and art of illumination from its standpoint of the eye as well as that of the wattmeter are well laid down in the article on "The Problem of Efficiency in Illumination" by Mr. Arthur J. Sweet, in this issue of the JOURNAL. The new lamps, the result of new scientific knowledge, require scientific principles in their use. It is these principles which Mr. Sweet presents in a simple and comprehensive way.

An important invention sometimes suffers because the conditions or methods of its application are unsuited or inadequate. Mr. Sweet shows how the higher candle-power units and the higher intrinsic intensity of the tungsten lamp have enforced new principles in applying the lamps.

These lamps have introduced another disturbance by radical departure from the old 16 c-p. carbon lamp standard to which everything had become comfortably adjusted. Commercial conditions have a difficult time in adjusting themselves to engineering progress; sometimes the introduction of useful inventions is retarded by commercial considerations and sometimes the advent of inventions brings on a financial crisis or a panic. In the case of the tungsten lamp the conditions are peculiar. The commodity is light. The public wants plenty of light of good quality and uniform intensity. A central station can furnish more light and better light cheaper by tungsten than by carbon lamps, but often concludes that it would not be advantageous to introduce efficient lamps. Why? Not because the company cannot furnish a better product (light) at a less cost, but because of a probably reduced income, for it furnishes light while it charges for kilowatt-hours. If it had so happened that a candle-power-hour meter instead of a kilowatt-hour meter were in common use, it would be possible to reduce rates so that a consumer could enjoy more light for less money and the central station could supply that light at less cost and larger profit than at present. The prevalent custom of making a uniform rate per kilowatt-hour is unsatisfactory. The charge is the same when the station load is small as it is at the time of peak load, and the rate is the same for the large user as for the small one. Commercial methods of charging for power are hard to adjust equably, even when kilowatts are wanted and are sold; they are still harder to adjust fairly when light is wanted but kilowatts are measured and paid for.

The tungsten lamp has been made principally in sizes of 40,

60 and 100 watts (or, in the old-time nomenclature, 32, 48 and 80 c-p., equivalent to two, three and five of the old 16 c-p. units). These are intermediate between the old incandescent lamp and the arc lamp. Hence, neither of the fields occupied by the common illuminants of a few years ago have been invaded by the new lamp. It has entered into an intermediate field, but it may not limit itself to that field.

The number of carbon lamps made annually in this country is nearly equal to the number of inhabitants. Assuming that the life equals the ordinary guarantees, there are one or two lamp hours per day per inhabitant. Hence the significance of a new illuminant which may, even in a small degree, extend the use and modify the physical, physiological and commercial characteristics of the incandescent lamp. CHAS. F. SCOTT

Administrative Positions for Engineers The officials of the Harriman Lines have introduced an innovation in the organization of the Nebraska Division of the Union Pacific Railroad that will be of interest to engineers concerned in transportation. The titles of Superintendent of Terminals, Master Mechanic, Division Engineer, Trainmaster, Traveling Engineer and Assistant Division Engineer have been abolished. The individuals to whom these titles formerly applied are now designated as Assistant Superintendents. They retain their former responsibilities and in addition are subject to administrative duties as well. The change is functional. Its object is to make the operating department of the railway self-perpetuating, which it is not on most American railways. The Harriman management regards the fact that, on all but few roads, advancement to the highest places is closed to the mechanical and civil engineer and open only to the transportation officers has something to do with the failure of the organization to become self-perpetuating. It believes that by broadening the experience of the officers in the three departments—transportation, motive power and permanent way, the company will have available a much larger number of competent men to select from when promotions are to be made. The whole matter is discussed in the Railroad Age Gazette of January 22d. The article in question, slightly abridged, appears in the present issue of the JOURNAL. In the discussion the "Gazette" states that the Harriman superintendents spend at least fifteen days of each month on the road. It also points out the danger of the operator, who remains long at the

desk, developing academic administrative habits. No great stretch of the imagination is necessary to see how these two observations can be profitably applied to the electrical engineer.

H. L. KIRKER

**The
Gary
Steel Works**

The construction of the great steel plant at Gary, Indiana, has attracted marked attention not only on account of its unprecedented size, but also on account of the various economies which are being introduced. Owing to its location the plant could be laid out as a whole without restrictions as to space or arrangement, thus making it possible to incorporate all of the best and most approved methods which have been found, in the experience of other mills, to be profitable and reliable. The builders have had available almost unlimited means and the accumulated experience of many years in numerous mills on which to base their plans for the erection of this immense plant. The site chosen is a strategical one. The location is central; it is a straight line down Lake Michigan to the harbor of Gary; railroad connections with all the roads centering at Chicago, the greatest railroad center in America, make the location desirable from the traffic standpoint. Gary is located about twenty-three miles southeast of Chicago on the southern shore of Lake Michigan and on the main lines of several of the great railroads. The site comprises some 9 000 acres with a lake frontage of nearly two miles. The present plant, however, occupies only 800 acres as compactness is a desirable feature in steel plants. After securing such a suitable location, the work of building a great steel plant, a fine harbor and a model industrial town was begun. The site was literally made over to order. The Calumet River was removed to a more convenient and straighter channel, the lines of four railroads which crossed the property were removed or elevated; a harbor was made, with a 250 foot channel and a 750 foot turning basin, and in order to secure additional room and deep water, the shore line was pushed out into Lake Michigan hundreds of feet. It is said that some $42 000 000 have already been expended on this plant and that some $33 000 000 more will be required to complete the work now under way. These immense sums are not being expended on any experiments. Only those methods, which have been thoroughly tested and found satisfactory in other plants, are being used. Although this is to be the largest steel works in the world, the blast furnaces used at Gary are not of the largest size, their capacity being 450 tons, while there are a number of furnaces in

existence of 600 tons capacity, but the size chosen has proved more manageable and profitable. The same may be said of the open hearth furnaces; in fact, the builders of this great plant seemed to care nothing for largeness for mere largeness' sake,—efficiency, saving, is the great object.

Transportation plays a very important part in a large steel works. One of the great advantages of being able to build from the ground up is the fact that the railroad tracks could be laid out to secure the best and quickest methods of transportation. A glance at the layout of the plant reveals an unusual arrangement of the furnaces and buildings. They are not laid out at right angles or parallel to each other but at the angles which will allow the quickest and safest switching. The furnaces are placed at an angle of twenty-two degrees with the main tracks, with long curves leading from the tracks to the furnaces. On these tracks trains of forty ton ladle cars can run quickly and safely. The open hearth furnaces are arranged in a similar manner, so that there will be little chance of blockades or delays.

Even the slag is not a waste product to be used in filling waste places but it is to be shipped to a great Portland cement factory a short distance away.

While the methods used in this plant have been fully tried out at other steel mills, this is the first one in which such absolute dependence has been placed on blast furnace gas. The great object of steel men has been to make "lean" gas, but even with the most improved furnace construction there is a vast amount of power available, which is here made use of for the first time in a large way. From the steel man's point of view, there are a great number of interesting features in this plant, but the feature which will doubt-less interest the greatest number of our readers is the production of power by the use of blast furnace gas. This is usually a poisonous by-product. At Gary it is used for heating the air blast in the immense stoves; under boilers to make steam for use at the blast furnaces, in pumps and other auxiliaries and for reserve power; in gas engines direct-connected to air cylinders for furnishing air blast to the furnaces, and in gas engines direct-connected to generators to furnish electrical power which is used for a great variety of purposes throughout the plant. The details of the method of developing power from this gas are given in an article on the "Gas-Driven Blowing Plant of the Indiana Steel Company" in this issue of the JOURNAL.

GAS-DRIVEN BLOWING PLANT OF THE INDIANA STEEL COMPANY

MECHANICAL AND OPERATIVE FEATURES OF BLOWING HOUSE NO. 3, AT GARY, INDIANA

THE practically exclusive adoption of gas engines at Gary for blowing the furnaces, as well as for electric service throughout the mill, represents the first decisive step in American steel manufacture toward full recognition of the development in gas engines which has been going on for the last ten years. Outside of German practice, which has been so conspicuously successful, the only forerunners of this great undertaking in America are the gas power plant of the Lackawanna Steel Company at Buffalo, and those of the United States Steel Corporation in the vicinity of Pittsburg and of Chicago. It is not to be expected that so important a property as the Gary works would permit of the least uncertainty in the matter of gas power application, and it is, therefore, to be assumed that the experience of the United States Steel Corporation has been successful.

The No. 3 blowing house, which is the first one to be placed in commission at Gary, is located at the extreme northern end of the power property next to the lake front. The building is shown in Fig. 1 and also all of that part of the furnaces and contiguous buildings which have been put into operation. Referring to the general plan of the northern group of furnaces, Fig. 2, the relative location of furnaces, dust catchers, preliminary washers, tower washers, boiler house, Theisen scrubber house, holder and blowing house, may be seen in detail. This first group of furnaces, Nos. 9 to 12, served by No. 3 blowing house, will also be duplicated for the second, first and fourth groups now under erection or contemplated, Nos. 5 to 8 served by No. 2 blowing house and Nos. 1 to 4 by No. 1 blowing house, these being provided for at the southern end of the property. These groups will be connected only by means of a five-foot gas main extending between the various blower houses and operating somewhat as an emergency tie line. Practically all operating functions of these groups are, therefore, self-contained, with the exception of the low service water supply and the air compressing plant by means of which the gas engines are started,

these being located at a central point in the electric power sta-
tion..

The general arrangement of one of the eight gas blowing
units is shown in plan and elevation in Fig. 3, together with air
blast, water, gas, air, exhaust and compressed air mains. The
building is about 600 feet in length and 104 feet in width. All
the units are spaced on 46-feet centers, including the steam blow-
ers, a standard dimension carried out in the other gas power
houses also. It is to be expected that in so large an undertaking
some steam reserve would be installed, which is the case and,
in fact, steam is a necessity for starting the furnaces. For each
group of furnaces there is a plant of 16 water tube boilers which
supplies steam to a pair of steam blowing engines; a pair of 2 000
kw steam turbines in the electric house; a steam turbine driven

FIG. I—GENERAL VIEW AT NORTH END OF GARY STEEL WORKS
Showing part of Nos. 11 and 12 furnaces at left and No. 3 blowing house
at right.

pump in the pump house; fire pumps, hydraulic pumps and steam
for miscellaneous purposes around the plant, such as steam coils,
oil settling tanks; for preventing the holder, preliminary washers
and gas valves in the various distributing lines, from freezing
during cold weather. This boiler house is fitted for burning
blast furnace gas. Thus it will be seen that the steam power
which is necessary to start a group of furnaces, also provides
reserve power at essential points to give the necessary.
security of operation. This same steam reserve will be provided
in each of the blowing houses to be built, as well as the electric
houses, so that nothing short of a general disablement will
result in the ever-dreaded stoppage of blast at the furnace
tuyeres.

The blowing house contains eight gas engine blowing units aggregating in capacity, 265 000 cu. ft. of free air per minute, and in addition, two steam units of 45 000 cu. ft. capacity. The layout contemplates that for each pair of furnaces, three gas units will be required with a spare, the steam unit being held entirely in reserve. These 450-ton furnaces each require 44 000 cu. ft. of blast per minute. As each blowing unit supplies 33 000 cu. ft. of free air per minute, the proportion of capacity will be evident. A gas cleaning plant capable of handling nearly 176-000 cu. ft. per minute is required. Here it is to be noted that the gas for the hot blast and steam boiler plant is only partially cleaned in the dust catchers and preliminary washers which remove the greater part of the heavier foreign matter.
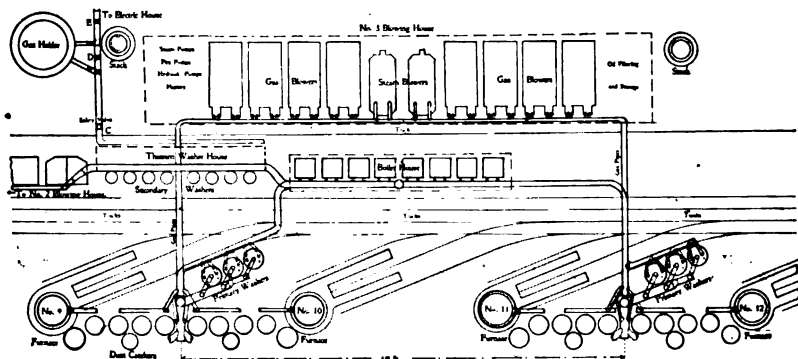
FIG. 2—OUTLINE PLAN OF GROUP OF FURNACES
Showing arrangement of furnaces Nos. 9, 10, 11 and 12, stoves, washing plant, blowing houses, etc.

It is estimated that about 30 percent of the blast furnace gas produced will be required in the stoves, leaving 70 percent available for outside purposes, or deducting ten per cent for boilers and loss in washing, somewhat over 60 percent for gas power. Consequently, the secondary cleaning plant of tower and Theisen washers has to take care of only a part of the gas produced. The purified gas, which will approximate 90 B.t.u. after the furnace burdens have assumed their normal condition, will develop 66 000 indicated hp in gas engines working at or near normal load.

The normal blast pressure for which this plant was designed is 18 lbs per square inch. Occasional increase in pressure to 25

or 30 lbs. maximum is provided in case the furnace burdens show a tendency to mass. At eight pounds pressure, the work required to compress 33 000 cu. ft. of free air per minute is 2 000 indicated horsepower. Assuming a ratio of 80 percent between the indicator cards obtained from the air and gas cylinders, this would be equivalent to 2 500 indicated hp in the gas engines. At the maximum rate of work, 28 000 cu, ft, of free air per minute compressed to 30 lbs. pressure, would correspondingly require about 2 500 air hp, or 3 000 indicated hp in the engine cylinders. In fact, one of these units was tested at air delivery pressures as high as 39 lbs. for some hours. A normal day's run shows an average of about 18 lbs. blast pressure with an occasional in‧crease to 25 lbs. for a period of about one-half hour, and also and hourly drop to about 5 lbs., occasioned by changing over the stoves or by casting.

The blast mains will be in duplicate, each separately connected to the two air tubs and controlled by individual valves. This duplication is necessary as one furnace may require full blast pressure while the other is casting on reduced pressure. To facilitate these operations, a 12-inch snorter pipe is employed to relieve the pressure on signal from the furnaces. Thus one air tub of a unit may be discharging at full pressure on the upper blast main while the other is doing comparatively little work at reduced pressure on the lower main. All the other valve operations are controlled at the furnaces. With a pair of furnaces working at full blast and three blowing units supplying them there would be a total period of from a quarter to a half hour once in five hours when reduced pressure is necessary, which totals about two and one-half hours a day, or only 10 percent of the time. This duplication of control valves is evidently necessary to "straddle" the load, and a twin engine works out very satisfactorily in this respect. Small variations in pressure of one or two pounds may be obtained by an unloading valve, which simply bypasses one of the air valves on the discharge of the compressor, thus reducing its capacity proportionately.

THE BLOWING UNIT

The general arangement of one of the blowing units is shown in Figs. 3 to 7. Fig. 3 shows an outline plan and elevation of a unit together with the arrangement of air blast, water, gas, air, exhaust and compresed air mains. A general view of the
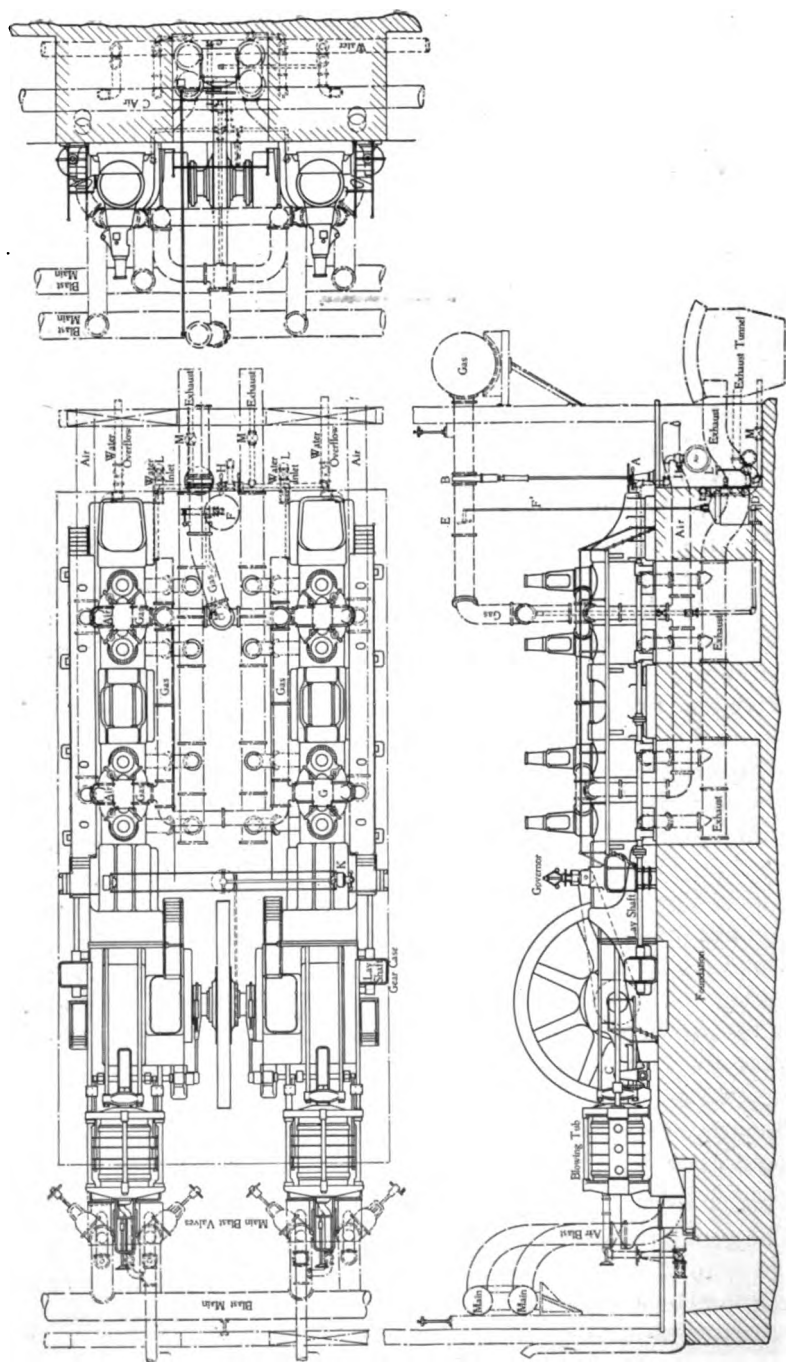
FIG. 3—GENERAL PLAN AND ELEVATION OF COMPLETE BLOWING UNIT

A—Inlet throttle valve stand. B—Inlet throttle valve. C—Distance rod. E—Butterfly gas inlet valve. F—Gasometer. F'—Butterfly valve rod. G—Gas and air manifold. H—Quick starting compressed air valves. J—Main compressed air valves. J—Snorter pipe.

interior of the blowing house is given in Fig. 4. General views of the blowing engines from the blowing end and from the power end are given in Figs. 5 and 6. The units are set down to the floor level with openings 17 feet wide between piers to provide access to the exhaust valves. This gives a depressed floor between the two sides, five feet below the main floor, with galleries running along the cylinders at the floor level, as shown in Fig. 7. There is ample space for working at the lower parts of the engine and handling them by the traveling crane. This avoids entirely the bad feature of an exhaust valve pit, which was encountered in early attempts to locate the engine at the floor level. Underneath this depressed floor which is of steel plate, are the exhaust lines.

The engine is of the four-stroke cycle, double acting type. The characteristic features of the engines are: simplicity, accessability of parts and reliability of working, three factors which must be given the greatest consideration in view of the character of attendance generally obtainable in this country. Both inlet and exhaust valves are driven from a single eccentric, Fig. 8, instead of individual eccentrics or cams, as is commonly the case, which simplifies both the valve gear and valve setting. The rolling cam motion employed for lifting the valves, relieves these eccentrics of the greater part of the work. When it is considered that the pressure required to lift one of these exhaust valves at the moment of release, may be as high as 2.5 tons, the advantage of this gear is apparent. It also permits a valve setting in which exhaust and inlet periods overlap, which makes possible a more perfect cylinder filling than would otherwise be possible and also a certain amount of scavenging due to the inertia of the incoming and outgoing columns of gases.

Cooling System—Fully one-third of the cylinder jacket is removable so that easy access can be had to the remotest jacket spaces. The desirability of this feature is apparent from previous experiences with clogging of cylinder jackets with muddy cooling water, and in fact, in this very plant, the operation was greatly interferred with in the early days by a sudden inundation of minnows which had entered through a defective intake screen and clogged every constricted passage in the cooling circuits. For this same reason, a mud ring is provided at the bottom of each cylinder exhaust jacket, which may be quickly slipped off without disturbing the exhaust valve cage, thus open-

ing the entire jacket space for cleaning with a hose. Cooling water is provided at a pressure of about 35 lbs. from a 16-inch main running the length of the building. A single valve controls each side of the engine and valves in each water circuit are provided so that the rate of flow once set, need not be changed. These separate circuits serve all the important parts, each having a visible overflow so that the quantity and temperature of the jacket water can be determined at any time. The cylinder jacket water enters first through the exhaust cover chambers, escaping into the cylinder at the bottom just under the exhaust port, ascending around the cylinder jacket to the top where it overflows, thus always keeping the jacket full. To further econ-

FIG. 4—GENERAL INTERIOR VIEW OF NO. 3 BLOWING HOUSE FROM SOUTH END

omize water, the pistons and heads are in series on the counter-current principle. After passing through the front and rear heads of the forward cylinder in series, the warm water enters the piston rod at the middle crosshead, thence through the piston and out at the front end. In all cases water enters at the bottom and overflows at the top of the chamber to be cooled. Telescopic supply pipes are used instead of knuckle joints which are difficult to keep tight in case of water carrying silt or other foreign matter.

Exhaust—The individual exhausts for each cylinder enter a 30-inch exhaust manifold (one for each side), which communicates with an 8 by 10 ft. brick tunnel running the full length of the building and discharging into a 6 by 100 ft. stack at either

end. All water from the engines drains into the exhaust tunnel, and its presence serves not only to cool the exhaust gases, but also to reduce their volume and consequently the back pressure on the engine. The resulting vapor incidentally forms an effective muffler. Deflecting nozzles are provided at each entrance to the manifold, which gives the exhaust gases a definite direction and thereby reduces the resistance of exit.

Some provision is necessary for sealing each of these manifolds, while men are working on the engines. This occurs in the form of a dip which may be filled with water and thus operate as a gas-tight valve.

GAS SUPPLY

Along the west wall of the building extends a 7.5 foot steel gas main resting on structural wall brackets and communicating to each blowing unit through a 24-inch supply pipe with gate valve and pressure regulating butterfly valve. The latter is required to reduce the pressure of the gas delivered to the engine to atmospheric pressure so that air and gas may be drawn into the engine always at the same pressure, and hence have the same proportion, as determined by the respective inlet valve settings. This butterfly valve operates, automatically from a small gasometer which communicates with the engine side of the butterfly valve.

AIR INTAKE

An especially neat feature is the method of conveying air to the engines. For this purpose, a duct or "riser," Fig. 9, is built into the engine room wall opposite each line of cylinders. Open louvres at the top give free access to outside air. These are protected by wire screens. This arrangement permits the use of a swinging door which is normally closed, but will readily open if there is an unusual pressure in pipe leading to the engine.

GOVERNING

Speed control is accomplished by means of a relay-type oil pressure governor. The essential feature of this system is that the actual work of moving the large valves is accomplished by an oil pressure cylinder working under a pressure of 50 to 60 lbs. from a plunger pump driven from the engine lay shaft. Thus the centrifugal regulator is relieved of all work except the operation of a small pilot valve. This oil pressure can always be noted at the engine gauge board and should the pump fail, a

small gravity accumulator serves to maintain pressure until reserve valves can be opened. In power gas work, where a large amount of dust and dirt is liable to be encountered, some form of relay system is imperative, otherwise the regulation would be largely dependent upon the condition and cleanliness of the mixing valve surfaces, which would be practically out of the question in all important installations. In addition to the main governor, a centrifugal safety stop device is provided at the rim of the fly-wheel, which trips the main igniter switch at a predetermined overspeed and shuts down the engine. Should the governor for any reason fail completely in its functions, the engine may be kept in service with mixing valves wide open and
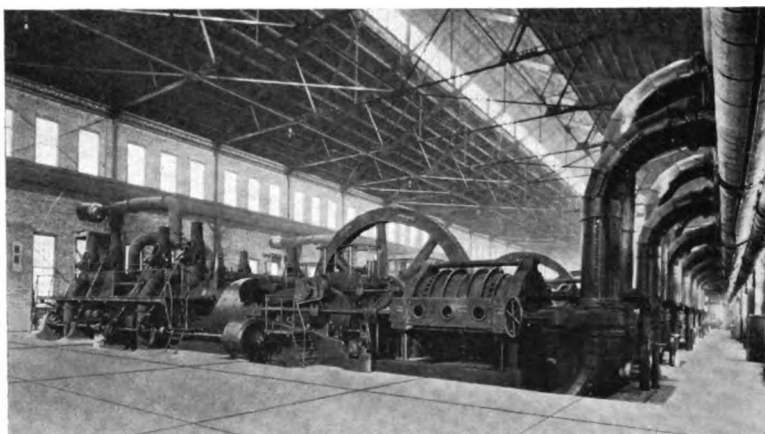
FIG. 5—GENERAL VIEW OF UNITS FROM BLOWING END

regulated by a man at the main throttle. Any tendency to racing could then be corrected by holding down the gas regulator which is close to the main throttle.

COMPRESSED AIR SYSTEM

The compressed air for No. 3 and No. 2 blowing houses, as well as the electric house, is supplied from a plant of compressors in the last-mentioned building. These are 14 by 18 by 12, two-stage machines geared to 50 hp motors and each provided with automatic valves unloading at 200 lbs. pressure. General practice is to provide a number of steel storage tanks for compressed air, holding the majority of these in reserve in case of break down of the compressing plant, but owing to the great

length of the buildings at Gary, the somewhat unique system of a single 30-inch lap-welded pipe main has been employed, extending the entire length of the building at the rear beneath the operating floor. Upon this main the entire plant is depenu- ent, but it is designed with sufficient strength to avoid a possi- bility of trouble.

So important a function as ignition again calls for reserve. At the engine three igniters are provided for each combusiton chamber, located at points in the cylinder corresponding to the vertices of an equilateral triangle. This accomplishes a two- fold purpose; first, it provides practically certain ignition in case of failure of one igniter, and second, insures more rapid combus- tion and consequently higher efficiency. All of these igniters are separately fused, so that a short-circuit of one will not render the others inoperative. Both poles are insulated from the cylin- der body so that a double ground is necessary to completely short-circuit an igniter. The make and break system is used exclusively on these engines. Experiments with the jump spark and other high tension systems, have all given uncertain results with the high compression used with blast furnace gas. With the magnetic igniter used, any number of duplicate igniters may be used in any position desired by running an insulated iron pipe conduit to the desired point, all these circuits converging in a rotary contactor or timer driven from the engine lay shaft. This is protected by an iron casing and runs in oil. By rotating the casing through a few degrees, as indicated by a graduated scale, the ignition may be advanced or retarded at will while the engine is in operation so as to obtain the best combustion with a given gas.

Ordinarily, the igniters receive current at about 110 volts from a small motor-generator set supplying each of the engine panel boards. The motor-generator, in turn, is driven from the alternating-current bus-bars of the electric power station. It is, of course, unavoidable that this distant source of supply will sometimes be cut off by accident. In anticipation of this event, recourse has been had to the storage battery house near by, and automatic apparatus is being constructed which will instantly throw the engine ignition circuit over to the storage batteries in case of trouble. And as the north and south sections of the

blowing house will be separated in this respect, the possibility of a complete shut down is exceedingly remote.

LUBRICATION

Both cylinder and engine oil is handled by automatic means, grease cups being used only on small moving parts such as links, valve gear, etc. In the design of the oiling system, provision has been made for the strictest economy in oil consumption. The continuous return system is used with settling tanks, filters and pumps in series. The system for No. 3 blowing house comprises, first, a 2 500 gallon storage tank resting upon the lower chords of the roof trusses. From this point, oil is distributed to some thirty different parts on each blowing unit at a positive
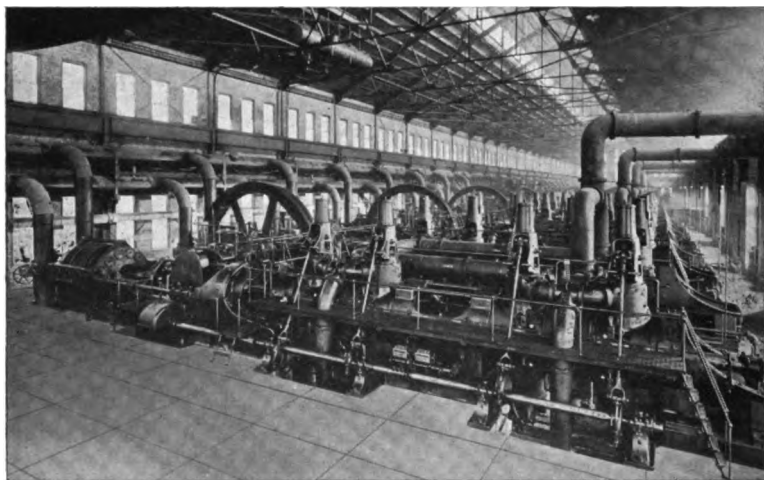
FIG. 6—GENERAL VIEW OF UNITS FROM POWER END

static head of about 25 feet.   A single valve controls each side of the unit, but the various circuits are served by four groups of sight-feed manifolds. These once adjusted for the proper rate of flow need not be changed, so that the work required to maintain proper lubrication is very small. All of the oil is returned to a common header leading to the basement filter plant.

Cylinder lubrication is also taken care of by automatic forced feed pumps driven from the engine lay shaft with the special feature that the eight individual circuits leading to various parts of each cylinder (including rod packings and exhaust valve stems), are accurately timed, so that oil reaches the cylinder just before

the end of the exhaust stroke. This allows two complete strokes of the piston before combustion takes place, during which the oil is spread over the surface of the cylinder. These cylinder oil circuits run about 12 drops per minute on the large engines at full speed. All of these lubricators are in conspicuous positions and it requires but a glance to observe whether both cylinder and engine oil are running freely. Should any stoppage occur, the oil would immediately back up in the feed and thus indicate the location of the trouble.

It is contemplated in the completed plant that all of these cylinder oil lubricators (32 in number) shall be served from a central point having a small meter in each feeder line to deter-the rate of oil consumption.

STARTING

The operation of starting one of these large units is comparatively simple. It is first necessary to unload the air tubs by means of the snorter valves. With the ignition current on and gas supply valves open, the compressed air valves are opened, thus supplying the various combustion chambers in proper succession. In two revolutions, the engine usually catches ignition and comes up to speed, automatically cutting off the compressed air by means of check valves at the cylinder which close as soon as the pressure of combustion exceeds that of the supply. In the meantime, the main valves for water and engine oil have been opened and the compressed air is shut off at the main, while the main gas throttle is opened cautiously to prevent overspeeding. In normal starting, the pressure in the compressed air main is reduced only seven pounds per engine, which evidently gives a very large margin of capacity for starting the entire plant, even if this were done in quick succession, as would seldom be the case. The most effective results are obtained by throwing both air valves wide open rather than to attempt starting on one side and with pressure throttled, as less air is used in a quick start. A typical start on No. 2 unit, was timed as follows; air valves opened; right valve off in five seconds; left valve closed in 15 seconds; all cylinders firing; engine up to speed, 40 seconds.

The high compression carried in these engines, 200 lbs. per sq. in., prevents their stopping on dead center, and in any event

they would start in any position as the cranks are set at 90 degrees angularity.

AIR BLOWING TUBS

The construction of the blowing cylinders embodies the essential idea of the Slick air tub, which is also in use at Bessemer, Homestead and elsewhere. Circumferential openings serve as inlet ports, while the piston is receding. Owing to the large exposed surfaces, these blowing cylinders run very cool, and only when operating at maximum pressure for a considerable time does the temperature increase perceptibly.
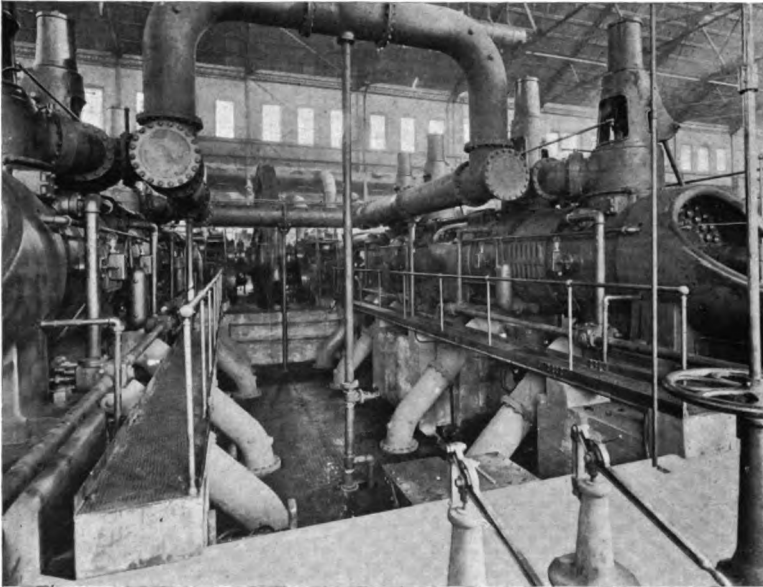
FIG. 7—VIEW BETWEEN CYLINDERS OF A BLOWING UNIT

WATER SERVICE

The pump house to the south of the upper group of furnaces serves the entire works at about 125 feet head and contains five 25 000 000 gallon turbine type motor-driven pumps, and a sixth unit of equal capacity driven by a steam turbine. This latter unit is complete with surface condenser, and is intended as a reserve, taking steam from the north boiler house. This pump house serves the gas engines, furnaces, washing plant and all other operations except the hydraulic-operated tables in the mills.

It is supplemented, by a group of pumps located at the south end of No. 3 blower house, which contains also the boiler feed pump and underwriters fire pumps, all steam-driven, the exhaust being utilized for heating the feed for No. 3 boiler house.

<div align="center">GAS CLEANING</div>

It may be noted that this plant differs from those in the Pittsburg district in that the closed top type of furnace is employed; i. e., with no explosion door. All of the large piping is designed to withstand a maximum pressure of at least 35 lbs. Relief vents are, however, provided at several points in the open water seals of the primary, secondary and Theisen washers, so that an explosion in the furnace, which did not choke itself out in passing through the tortuous passages of hot blast stoves and piping, would relieve itself at one of the above-mentioned vents.

The dust catchers are of standard construction, but the primary washers are an improved type of Mul-

FIG. 8—DETAIL CROSS-SECTION OF GAS ENGINE THROUGH VALVE CENTERS

lin washer, consisting of a central conical distributor suspended about an inch above the surface of the water which is maintained at a constant level by an overflow. The edges of this cone are deeply fluted, resembling in plan the form of a star-fish, so that the maximum of periphery is presented to the gas which is thus forced to spread out in a thin sheet over the surface of the water. Here the greater part of the suspended dust is deposited and drawn off below. In the tower static washers the gas is forced to ascend through a lattice work continuously wetted with Korting

sprays. It is also passed through several sheets of falling water obtained by conical baffles arranged in series at the base of the washer. In the Theisen house final cleaning is accomplished, and the gas delivered to the mains with only 0.02 grains of foreign matter per cu. ft. This is ample for gas engine work. and in the Pittsburg district exceeds at times the purity of the air at the engine intakes. A similar cleaning plant at the Bessemer works, has shown gas as clean as 0.002 grains at times, averaging about 0.02, while the effect of a slip in the furnace is to increase this considerable.

All of the overflows, from the water seals of primary tower and Theisen washers, are returned to settling basins 20 by 40 by 12 ft. deep, arranged so that the heavier material will have an opportunity to settle out, and may be reclaimed, thus avoiding clogging up the sewers with this material. A central division wall provides two compartments, one of which may be in use while the other is being cleaned.

POWER ORGANIZATION

Much of the ultimate success of the Gary undertaking depends directly upon the efficiency of the operating force. Many of the more perfunctory operations have been taken out of the hands of the operators by the use of automatic appliances, yet a high order of intelligence is required in the few men entrusted with the operation. These men must use head more than hand. It may be supposed that so large a plant would require an army of men to operate it, but such is not the case. In normal operation, No. 3 blowing house will be in charge of a chief engineer for each operating watch. Each engine crew will consist of but three men, an engineman and two oilers. These oilers will handle the blast valves during the furnace operation and the water, gas, oil and air valves when starting up, with
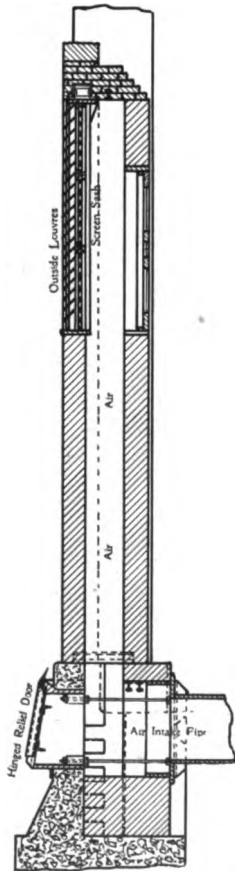
FIG. 9—DETAIL SECTION OF AIR INTAKE LOUVRES

the engine driver in direct charge of the throttle. This makes a power house crew of about 20 men for handling 25 000 hp in gas engines. Considering that much of the actual work occurs in operating the valves of the blowers, it will be seen that the amount of labor required for these engines is exceedingly small, and, in the case of the electric units, even this might be reduced.

TABLE I—DATA ON NO. 3 BLOWING HOUSE

Size of building.......................................	104 x 598 ft.
Foundation—3 ft. concrete monolith on sand.	
Height building to crane rail........................	28 ft.
Depth basement	12 ft.
Bays (26).	space 23 ft.
Engine centers spaced................................	26 ft.
Cylinders, centerline to centerline....................	23 ft.
Length blowing unit over all.........................	87 ft.
Diameter of fly wheel................................	24 ft.
Size cylinders, Diam.................................	gas 42 in., air 68 in.
" " Stroke................................	54 in.
Main bearings ....,.......	54 in. x 30 in. diam.
Crank pins	16 in. x 17 in. diam.
Piping—Air and gas at inlet..........................	16 inches.
" — " leaders.................................	22 inches.
" —Exhaust at engine...........................	20 inches.
" —Gas supply leader...........................	7½ ft.
" —Exhaust headers	30 inches.
" —Blast main	42 inches.
" — " risers.................................	28 inches.
" —Water main	16 inches.
" —Compressed air main........................	30 inches.
Piston rod	12¼ in. x 20½ ft.
Bore piston rod......................................	5¼ in.
Depth of water jacket................................	4-5 in.
Ratio crank to connecting rod........................	5½ to 1.
Piston speed—Blowers, 675; electric 750 ft. per min.	
Compression, per sq. in. maximum....................	200 lbs.
Rating of unit, free air per minute...................	33 000 cu. ft.
" " " maximum speed	75 r.p.m.
" " " delivery pressure	18 lbs. per sq. in.
Maximum rating (28 000 cu. ft.).....................	30 lbs. per sq. in.
Engine capacity (rated and max.)....................	3 400 to 3 750 indicated hp.

No. 3 blowing house was started the first week of January, 1909, and during the month, four gas units were put into commission, sufficient for the first pair of furnaces. The remainder are completely erected and will go into service as soon as furnaces Nos. 9 and 10 are blown in.

A NEW PLAN OF OPERATING ORGANIZATION ON THE HARRIMAN LINES

A N interesting and important experiment with a new form of maintenance and operating organization was begun on the Nebraska Division of the Union Pacific on January 14. On that date an order was issued substantially as follows:

Each of the nine assistant superintendents (mentioned in the order) continues charged with the responsibilities heretofore devolving upon him, and in addition assumes such other duties as may from time to time be assigned. Such of the above as are located in the same building have one consolidated office file in common with the superintendent.

All communications on the company's business, originating on this division, intended for the superintendent, or for any assistant superintendent, should be addressed simply "Assistant Superintendent," no name being used unless the communication is intended to be personal rather than official, in which case it will be held unopened for the person addressed. It is intended that an assistant superintendent shall always be on duty in charge of the division headquarters offices during office hours. No officer should sign the name or initials of another.

Train orders will be given over the initials of the Chief Despatcher.

The modification of pre-existing organization and methods herein ordered have been carefully worked out to expedite the company's business by the reduction and simplification of correspondence and records. It is expected and believed that officers and employes will insure a successful outcome by lending their usual intelligent co-operation and hearty support.

The change is not merely titular, but, as the circular shows, is functional; it involves a modification and broadening of the duties of all affected. If the experiment works well it may be the forerunner of an important reorganization of the entire maintenance and operation department of the Harriman system.

The purpose of this change, and of others more extensive that are contemplated, is both to strengthen the existing operating and maintenance department, and to make it a better school for developing capable, resourceful, all-around operating officers. The operating department has three sub-divisions, the transportation, the engineering, or roadway, and the mechanical. The hardest problem railway managers have is to get a simple and satisfactory correlation between these sub-divisions, and men competent to preside over all of them in the offices of superintendent, general superintendent, general manager and operating

vice president. The management have given hard study to the subject, and are of the hope that the plan referred to will be found to be a solution of this vital problem.

In the way of strengthening the present organization, it will be noted that one of the effects of the change will be to destroy what has been facetiously but aptly termed, "government by chief clerks." Ordinarily when the superintendent of a division—or, for that matter, the general superintendent or a higher officer—is away from his office, his chief clerk writes letters and orders to which he signs his superior's name. As superintendents on the Harriman Lines are required to be on the road at least 15 days in every month, their chief clerks are practically acting superintendents one-half of the time. Now, the chief clerk usually is a very faithful, experienced and competent employee, but he seldom has the equipment to perform the duties of superintendent. Under the plan being experimented with the work of the chief clerk will be confined to the supervision of the office force and the handling of statistics. The senior assistant superintendent will have no expense account; he will be in charge at headquarters throughout every working day. All communications on the company's business originating on the division and addressed to headquarters will be received and answered by him. In the absence of the superintendent, he instead of the chief clerk, will be acting superintendent.

There is always danger that a railway operative who is kept long at a desk will develop the academic tendencies of office government. For this reason, the senior assistant superintendent, after being kept at headquarters four or six months, will be assigned to other duties for which he is fitted, and some other assistant superintendent will take charge at headquarters and while there will be senior assistant. Thus each of the assistant superintendents, who formerly had the various titles of division engineer, master mechanic, tranmaster, etc., may perhaps serve in rotation at headquarters, and get experience in supervising the operation of the entire division. Each will know all about either the transportation, or the mechanical or the engineering departments of the division, according to his special training, and something about each of the other departments.

Each assistant superintendent has an office at headquarters,

but is forbidden to keep a separate office file. He is permitted to write only a few letters to subordinates in his particular branch of the work, for which he still retains full responsibility. He may not write letters to his fellow heads of departments next door; all letters for them must be addressed to the senior assistant superintendent. He may not write letters to superior authority direct, but must submit them for the signature ot the superintendent. Duplication of letters and instructions ,is prevented by the major portion being dictated by the senior assistant at headquarters. It is believed that by this system the number of letters written will be reduced 40 to 50 percent; and that, relieved from the care of a bureau of papers, and from handling a great deal of correspondence, each officer will be able to spend much more time on the road or in the shops, and in thinking about and intelligently planning his work.

While the officials of this division of the Union Pacific were the first to ask for an opportunity to try the new scheme, it is expected that it will be tried on other parts of the Harriman Lines as fast as details can be worked out to meet local condition.

It is expected that discipline will be improved by the fact that each officer, like the officer of a vessel, has the authority indicated by his title. Each assistant superintendent, regardless of his special work, will have authority over every officer or employee of lower rank, whether locomotive engineer, conductor or mechanic. The former master mechanic, now assistant superintendent, can tell the young brakeman that the safety of the public will be increased by prompter flagging next time without being liable to an impudent reply. The late division engineer can help do missionary work in the direction of careful stoking. The former traveling engineer can advise the conductor as well as the engineman how better to get trains over the road. Each assistant superintendent, because of his having general jurisdiction over all departments, will naturally begin to note and suggest defective appliances and methods and possible improvements outside as well as inside his special line. If a blockade or an accident occurs the superintendent can scatter his assistants to the crucial points. On arrival each has authority over all available forces instead of over only a part. Back at the headquarters is the senior assistant controlling all the interlocking levers of administration. The new system of organization is based on the conception of all-around administrative usefulness to

supplement the necessary specialization of the individual officer in his particular branch.

It is expected that the same principle of organization will be applied to other operating units, both above and below the division. Already it is being arranged on some small terminais to have the roundhouse foreman become also yardmaster. Where the volume of business is too heavy for such a dual position the one officer may be appointed the assistant of another. It is desired to bury the old post-mortem question of whether the train or the engine was ready first. An extension upward of the same principle of organization would make the general superintendent, the general superintendent of motive power and the chief engineer, all assistant general managers, with general and special authority and duties similar to those of the assistant superintendents of a division.

The foregoing indicates some of the ways in which it is expected the new scheme of organization will tend immediately to strengthen the maintenance and operating department. But it is being tried more for ultimate than for immediate results. Its keynote is, "Education." The best criterion of the perfection of any organization is whether it is self-perpetuating. It was said of Napoleon's army that every private carried a marshal's baton in his knapsack. This was one way of saying that no rule, precedent or custom barred an able fighter, no matter what his rank or training, from aspiring to the highest commands. The result was that every man was stimulated to attain the highest efficiency, and that when an officer fell there was always present someone fitted to take his place. Now, something like this, it is conceived, should be true of railway operating and maintenance organization. The railway operating department is a great army; at high-water mark in 1907 there were 118 000 men on the payrolls of the Harriman Lines. An army is divided into cavalry, infantry and artillery; it has staff as well as line officers. Similarly, a railway operating department has its transportation, mechanical and engineering sub-divisions. That most of the fighting of an army is done by infantry, does not prevent an artillery or engineer officer from rising to the rank of marshal or lieutenant general. It is well-known that few American railway operating departments are self-perpetuating. When the office of general superintendent, or general manager or vice president becomes vacant the management is

apt to go to some other road for a man of enough ability and breadth of experience to fill it. It is well-known also that on all but a few roads only transportation officers can hopefully aspire to the highest places. Except on the Pennsylvania, the civil engineer seldom gets higher than chief engineer; the mechanical man seldom gets higher than superintendent of motive power. Numerous railway presidents have risen through the transportation department from telegraph operators, and a legion of vice-presidents have come up the same way. The number of civil engineers who have risen to the top is relatively small and the number of mechanical employees still smaller. Scattered far apart, indeed, are the former locomotive enginemen, whose native ability and indomitable energy have enabled them to climb to the top.

It is believed that with over 100 000 men in their employ, the Harriman Lines, wth the right kind of organization, should be able to train and develop plenty of men as able and as broad in experience as can be found elsewhere, and who will have the additional advantage of close familiarity with the methods, equipment, etc., of these lines. In order to develop plenty of men from whom to select officers to preside over the various grades and sub-divisions of the operating department, something should be done to open wider the door of opportunity to the engineering and mechanical officers, and to broaden their training and experience, as well as those of the transportation officers.

Under present conditions on most roads it is natural that only transportation men should rise to superintendents, general managers and vice presidents. The primary work of the railway is to furnish transportation; keeping motive power and roadway in good condition is auxiliary to this. The main work of the superintendent, therefore, is to get trains over the road. When he looks about for an assistant superintendent he may find no one who has had experience in this work, but the trainmaster, usually a former despatcher; so the trainmaster becomes assistant superintendent. Just as naturally, when the office of superintendent becomes vacant the assistant superintendent gets it; and so it usually goes clear up the line. But suppose the superintendent had on his staff a man of much natural ability who was a mechanical or engineering expert and who also had had some experience and had developed skill in getting trains over the road; in such a case, when the superintendent was pro-

moted he would be apt to recommend the former master mechanic or division engineer as his successor.

The main object, then, of making assistant superintendents of the former division engineers, master mechanics, traveling engineers, etc., is to give to each of them broader training and opportunity so that not merely the transportation man, but the man, whatever his special work, who has shown the most ability, can be advanced. Similarly, the object of making assistant general managers of general superintendents, superintendents of motive power and chief engineers would be to give them all a broad training and experience so that the management would not be forced either to promote a transportation specialist to general manager or go to another road for a man to fill that office, but could choose for it the assistant general manager who, regardless of his special line of work, had shown the greatest capacity for supervising the work of all the departments. The change, it is believed, would make officers more capable, both by broadening the experience of all and by stimulating the energies of many through greater opportunity, and would give the management about three times as many capable men to select from in filling the more important offices.

The scheme, avowedly, is in a tentative stage. That the ordinary operating and maintenance organization has imperfections is recognized by all thoughtful railway operatives. Many may doubt if the experimental, quasi military method being tried on the Harriman Lines will prove the cure for those imperfections. But all, at least, will be glad a new scheme is being tried by such capable hands and will study the results with the greatest interest. (Condensed from the *Railroad Age Gazette*.)

THE PROBLEM OF EFFICIENCY IN ILLUMINATION

ARTHUR J. SWEET

I N most fields in which the engineering sciences are applied the question of efficiency is one which must receive the serious consideration of both the designing engineer and the man who pays the bills. In few of the applied sciences, however, is efficiency of such such supreme importance as in illumination. In the application, for instance, of the electric motor the primary consideration is usually reliability, while efficiency, though important, is none the less a secondary consideration. In the air brake or signal systems, reliability of service is vastly more important than efficient power consumption. In illumination, however, efficiency of operation is a consideration so paramount that it may rightly be called *the* problem of illumination.

There are possibly two questions which may be raised by those who hesitate to accept the statement that the problem of illumination is essentially a problem of efficiency. One party may say, "We agree that the issue is one of satisfactory illumination at low cost. But is efficiency of operation the all-important factor of the cost? Is not the useful life of the illuminating apparatus of equal or greater importance?" The question here raised can easily be settled beyond dispute and once for all. Those who are most apt to lay great importance on the question of useful life are those who use the incandescent lamp. In Fig. 1 is shown the relation which the renewal cost of the lamp bears to the power consumption cost at different costs of power per kilowatt-hour. The curves apply to the 16 c-p, 3.1 watts per candle, 110 volt carbon filament lamp. Curve *A* represents the renewal cost expressed as a percentage of the total cost of operation, including renewal. Curve *B* represents power consumption cost, likewise expressed as a percentage of the total cost. These curves show that, within the range of cost at which electrical energy is commonly available to the user of light—8 to 15 cents per kw-hr.—the renewal cost is almost negligible as compared to the cost of power. If a less efficient lamp had been taken as an example, the life of the lamp would have appeared as a still less important factor.

In the case of gas in open burners, and spirit or oil illuminants, the life of the illuminating apparatus is a very trivial factor in the total cost of operation. In the case of the gas mantle, the Nernst

lamp, the mercury vapor lamp, or any of the various forms of arc lamps which are in commercial use, the renewal cost bears to the power consumption cost a relation similar to that which has already been found true for the incandescent lamp in that the useful life of the apparatus is of minor importance, as compared with efficiency.

Others may assert that the artistic quality is frequently of more importance than efficiency. If artistic merit and efficiency were antagonistic or even independent principles, these critics would be right; but in illumination, as in many another applied science, art and efficiency go hand in hand. Not all so-called artistic installations are efficient; but the truly efficient installation is almost invariably artistic. For example: a false sense of the artistic decrees that incandescent lamps should not be suspended vertically from the chandelier. but at an angle to the vertical. The same artistic sense has surrounded lamps with a reflecting glass shade. With such an installation, the light is thrown directly in the face of anyone facing the chandelier. The result is not merely un-
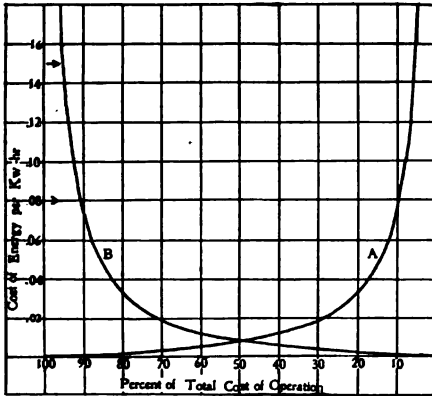
FIG. I—CURVES SHOWING THE RELATION OF COST OF RENEWAL (A) AND POWER CONSUMPTION COST (B) OF 16 C-P., 3.1 WATTS PER CANDLE, 110-VOLT CARBON FILAMENT LAMP

pleasant, but inartistic in the highest degree. Had the problem of efficiency first been studied, it would have been found that the most efficient position, the vertical, is also the most artistic in the illumination results obtained.

The general laws upon which efficiency of illumination depend are the fundamental laws of the science of illuminating engineering. Our natural and only logical procedure, therefore, is to analyze the various factors which determine efficiency of illumination and to recognize and classify the laws according to which these factors act. At the outset, it is necessary to have a clear conception of what is meant by efficiency in illuminating engineering. In the older engineering sciences, efficiency is the useful energy out-put divided by the energy in-put, expressed as a percentage; and in most engineering work the end sought is the transformation of one pure-

ly physical form of energy—mechanical, electrical, chemical—into another purely physical form. In illumination, however, the end sought is a physiological process, sight. The difficulty of measuring efficiency of illumination at once becomes apparent. Watts and horse-power can be reduced to a common unit, but what common unit can be found between watts and the sensation called clear vision? Does clear vision, under different illumination conditions represent always the same amount of energy expended in the physiological process? Can, indeed, any satisfactory unit of "clearness of vision" be found, whether energy unit or otherwise? The illuminating engineer has as yet no *unit* of efficiency. None the less, the term efficiency can be used and the distinctions of higher and lower efficiency can be drawn. In illumination there is, for any given installation, a fairly definite condition known as "good illumination". For any given plane of reference, or for any combination of such planes, the relation of efficiencies of two different schemes of illumination will be the inverse relation of the energy in-put required to produce "good illumination" in each case.

"Good illumination" is indeed a rough and inexact measure for a science seeking to be exact. However ill we like it, we will be the better engineers for clearly recognizing that it is at present the only measure we have of useful, energy out-put, of the energy which is active in stimulating the optic nerve and producing visual perception.

This, then, is the situation in which the illuminating engineer finds himself. His problem is fundamentally a problem of efficiency, the problem of using energy so as to accomplish the greatest amount of useful work measured in terms of visual perception. He has as yet no unit of efficiency and hence cannot measure efficiencies in absolute terms. He can, however, compare the relative efficiencies in inverse terms of energy in-put required to produce certain condition of visual perception popularly termed "good illumination". He can, moreover, determine the laws on which efficiency depends and apply those laws so as to produce highly satisfactory practical results, even though he cannot express in absolute terms the results attained.

When the term "efficiency of illumination" is considered closely, it is seen that in this term is included the combined effect of three different kinds of efficiencies. First, there is the efficiency of visual perception, this being the efficiency with which the eye receives light energy and transforms it into visual perception. Second, there is the efficiency of light distribution, by which is meant

the relation between total light energy generated and light energy useful in producing desired conditions for visual perception. Third, there is the efficiency of the light source, by which is meant the efficiency with which chemical or electrical energy is tranformed into light energy. None of these factors is trivial, each is of importance in determining the resultant efficiency of illumination. It has been the error of the past to lay all the emphasis on the efficiency of the light source.

To obtain efficient illumination we must have efficiency of visual perception, of light distribution, of light source,—all three. What, then, are the conditions upon which each of these three kinds of efficiencies depends?

EFFICIENCY OF VISUAL PERCEPTION

Efficiency of visual perception depends upon three conditions. These are, (a) the intrinsic brilliancy of the light source and of the surrounding light-reflecting objects; (b) the color of the light, and (c) the intensity and steadiness of the light. Each of these conditions will be briefly considered in turn.

Intrinsic Brilliancy of Light Source—The eye adjusts itself to various degrees of light intensity by the automatic expansion or contraction of the pupil or opening in the iris diaphram through which light is admitted to the eye. Now the light which is active in causing a greater or less contraction of the pupil is not merely the light which comes from the center of the field of vision, but the light which comes from the entire field of vision. The light which is active in causing visual perception, however, comes under normal conditions entirely from the central portion of the field of vision. The same amount of light, therefore, falling upon and reflected from the given visualized object may produce very different degrees of illumination due to changes in the size of the pupil, such changes resulting from differences in the intrinsic brilliancy of the outlying portions of the field of vision.

For example:—A person sits reading, say, in a room with dark-colored walls, the only source of light being above and behind the reader, entirely outside of his field of vision. Photometric measurements of light intensity on the printed page give results of two foot-candles. The reader calls it good illumination. Now we will introduce a second light source, say, a brilliantly incandescent Welsbach mantle or a tungsten lamp, into the reader's field of vision, screening the printed page so that it gets no light from the new light

source.   Gradually we will bring the new light source nearer to the center of the reader's field of vision.   Gradually the pupils of his eyes contract, admitting to the retinas less and less light from the printed page.   When the new light source, still screened from the printed page has been brought near the center of the reader's field of vision, photometric measurements are again made and the results again found to be two foot-candles.   "I know nothing about your foot-candles", is the reader's impatient reply, "but I call it mighty poor illumination".

Brightly lighted, white or very light colored walls may have an effect in contracting the pupil similar to a bright light source in the field of vision.   The serious decrease in efficiency which results from brilliant light sources or brilliantly lighted white walls is given recognition in the following concrete rules of practice:—

Whenever a brilliant light source is placed so that it may come within the field of vision, reduce to a low value the intrinsic brilliancy of the light source by a diffusing sphere, bowl, stalactite or bell-shaped shade.   Never use a bare incandescent lamp, nor a Welsbach mantle with no other shade than the clear glass chimney or mica chimney.

Do not illuminate light-colored walls or ceilings too brilliantly. This last rule and the physiological conditions which justify it are ignored by those who recommend installations of what is usually called cove-lighting.

Color of Light Used—With the same light intensity as measured in foot-candles, lights of different color give appreciably different illumination values.   Where objects of a great variety of color are to be viewed, the best light has the quality of summer day-light, i. e., light containing all wave lengths, but having a slight preponderance of the green rays.   For illumination of black and white effects, as draughting-room illumination, it is an open question whether modified white light, such as that just described, or green light, as of the mercury vapor lamp, is best suitable.

Intensity and Steadiness of the Light—It is a common fallacy to assume that the more the light the better the illumination.   As a matter of fact, for any given light intensity in the outer portions of the field of vision there is a corresponding definite intensity of light for the central portions of the field of vision which will give best conditions for visual perception.   Greater intensities than this will produce gradual or rapid fatigue of the eye, resulting in less clear vision.   A flickering, unsteady light also produces rapid fatigue of the eye functions.   For this reason the old-style open gas burner,

when used, should always be protected from air currents by a chimney.

Increased efficiency of visual perception may be obtained by detailed application of the following general rules:—Reduce to a low value the intrinsic brilliancy of all light sources exposed to the eye, avoid intensity of light on light-colored walls or ceilings. Use light of correct color value; avoid unsteady light, and avoid excessive intensity of light on surfaces which are constantly or frequently objects of visual perception.

EFFICIENCY OF LIGHT DISTRIBUTION

Efficiency of light distribution depends upon two important factors:—(a) the distribution of light which emanates from the illuminating unit and (b) the size of the unit and the location of centers of light distribution. Excluding mirrors and surfaces especially prepared for reflecting purposes, when light falls upon any of the surfaces with which we are commonly surrounded, a very considerable percentage of it is absorbed, while the rest is reflected. To give average figures, the percentage of light which is reflected from differently colored papers is as follows:—

TABLE I.

White paper...............................	80 percent
Orange paper..............................	50 percent
Yellow paper..............................	40 percent
Light pink paper..........................	35 percent
Light blue paper..........................	25 percent
Emerald green paper.......................	18 percent
Dark brown paper..........................	10 percent

From the table it is obvious, that, if light is to be used efficiently, it must not undergo many reflections, losing in each as it does under average conditions say 70 percent in intensity. Ideal efficiency of distribution is obtained only when all the rays emitted by the illuminating unit proceed directly and in proper proportion to the various surfaces to be illuminated, whence they are reflected into the receiving eye. Suppose an illuminating unit emits in one direction more rays than required to give the proper illumination of surfaces *A*, *B*, and *C* on which they fall. A large number of these additional and unnecessary rays will be absorbed and such of these rays as are not absorbed will be diffusely reflected. Now these diffusely reflected rays will decrease rather than increase the effectiveness of illumination of the surfaces, *A*, *B*, and *C*, for without them the degree of illumination would be correct. Most of these diffusely reflected rays, however, will not enter the eye, but will fall on the other surfaces, *D*, *E*, *F*. Here there will be another absorption.

The few rays that remain may, it is true, be useful in the illumination of the surfaces, *D, E, F,* but at a great sacrifice of efficiency.

The facts here given are so well known that detailed discussion of them seems trite. Nevertheless, they are largely ignored. There are few present installations in which the power consumption required could not be halved, or the efficiency of illumination doubled by utilization of the light now needlessly wasted through absorption. Here, then, is a factor just as important for efficiency of illumination and just as deserving of attention as the recent developments in high-efficiency incandescent lamps.

None of the light sources of themselves give such light distribution that all the rays emitted by the illuminating unit proceed directly and in proper proportion to the various surfaces to be illuminated. The Nernst lamp and the inverted gas mantle give better distribution than any of the other largely used light sources, but even the distribution of these is unsuitable when high efficiency of illumination is sought.

Uses of Shades and Globes—Fortunately the distribution of the bare light source can be greatly modified and highly efficient distribution obtained by the use of reflecting or refracting shades or globes. Of these, prismatic glassware is much superior to all others as best accomplishing the desired results; indeed, where strong concentration is wanted in one direction, and at the same time a small amount of light in all other directions—a frequently desired form of distribution—prismatic glassware is the only means at present known which will accomplish this result. For broad downward distribution of light, satisfactory results can be obtained by the use of suitably shaped opal or green-enameled glassware. The etched glass shades so frequently used are inefficient, and unsuited for properly modifying the distribution. Where large areas are to be illuminated from a few light sources, excellent distribution can be obtained by the use of sand-blasted or opal globes with flat conical reflectors of green enameled or opal glass mounted immediately above the lights.

The application of suitable glassware to give proper distribution results in a problem, the solution of which should not be attempted by engineer or layman unless he is especially trained and fully qualified as an illuminating engineer. No educated man, much less a scientifically trained man, would think of going to an optician's store and selecting a pair of eyeglasses because the curvature of the lens looks suitable, or because the mounting was artistic. Yet no less ridiculous procedures are of common occurrence in

connection with illuminating problems. The writer has known trained engineers, in some cases men of unusual ability, to install prismatic glassware without even knowing the distribution effects given by the particular type in question. Perhaps sharp downward concentration was desired; yet the reflectors were installed in utter ignorance of whether they threw maximum light downward, or maximum light laterally with minimum light downward. And when poor illumination results were obtained, as was to be expected, the conclusion was drawn that prismatic glassware was a greatly overrated product. The problem of obtaining efficient distribution of light is one requiring for its solution specialized knowledge of the physics of light and of the materials of illumination, and a broad experience with illumination installations.

The foregoing may be summarized and emphasized as follows:

1—A correct distribution of light about the illuminating unit is an indispensable condition to efficient illumination and low cost of operation.

2—No light source now on the market gives of itself correct distribution. Hence, suitable glassware to modify and correct the distribution should invariably be used.

3—The problem of correct distribution and proper means of obtaining it is a highly technical problem to be solved only by a competent illuminating engineer.

The size of the illuminating unit and the location of centers of light distribution is a second important factor in efficiency of distribution. Each installation is so much a particular problem that it is difficult to lay down any universal laws expressing the relation of these factors to efficiency of distribution. The following rules, however, will be found to have a general application. The center of light distribution should be located over each point of which relatively high intensity of light is desired. The need of additional centers and the location of such varies with the particular problem. Avoid too many centers of distribution. More artistic results and better efficiency are obtained when the light comes from clearly marked sources. The application of this rule will, however, sometimes require a large number of centers of distribution; for instance, in draughting-room illumination.

Several smaller illuminating units adjacently located at the same center of distribution give more efficient effects than a single larger unit. The most suitable number of units for one center of distribution is usually three, four or five. Do not locate an illuminating unit on a wall bracket or closely adjacent to a wall. If wall

brackets are insisted upon on account of their supposed artistic effect, a small light source surrounded by a relatively large diffusing globe should be used. By this arrangement the so-called artistic effect is attained without introducing any objectionable factors into the illumination. The actual illumination will, of course, be obtained by means independent of the wall brackets.

In applying the above rule to residence lightning, and observing the principles already stated, that too much light is just as much to be avoided as too little light, it will be found that small light sources are required. In residence lighting, cases are very unusual where light sources of mean spherical candle-power greater than 20 candle-power can be used without considerable sacrifice in efficiency. A light source of mean spherical candle-power of from eight to ten has the largest application in residence lighting. It is in this feature that the incandescent lamp has its greatest advantage over other illuminants;—it is readily obtainable in whatever size it is most efficient for the particular installation.

EFFICIENCY OF LIGHT SOURCE

The efficiency of the light source is the third kind of efficiency with which the illuminating engineer has to deal. Efficiency of light source depends primarily upon a single factor,—namely, the temperature to which the incandescent, light-giving body is raised. A clear idea of the relation of the temperature of the incandescent body to efficiency of light generation may be obtained by reference to Fig. 2.* The curves show graphically the various steps in the phenomenon of light generation. When sufficient heat is imparted to a body to raise it to a low temperature, say 100 degrees C., the body radiates energy in the form of long period ether waves. These waves are capable of stimulating certain nerves of the skin, and from this we have come to call them heat waves. These waves, it should be noted, have not the power to stimulate the optic nerve. If now, the temperature of the body be raised to 600 degrees C., a larger amount of energy is radiated, and the radiations are over a broader range of wave-lengths. Some of the shorter of the waves now generated are capable of stimulating the optic nerve. These waves are called light. On raising the body to a higher temperature, a still larger amount of energy is radiated over a still broader range of wave-lengths. The shorter of the waves now produced are incapable of stimulating either optic nerve or nerves of the skin; but

*These curves are from an article by Mr. E. P. Lewis in the California Journal of Technology of April, 1907.

these very short waves are especially active in producing chemical changes and hence they are sometimes called chemical waves. As the temperature rises the total amount of radiating energy increases, the increase being chiefly in the shorter wavelengths; hence the proportion of light waves to total wave energy or efficiency increases as the temperature increases. The curves apply equally to any incandescent solid whatever its chemical constitution. They therefore apply to all light sources in practical commercial use except the mercury vapor and other vapor lamps.

FIG. 2—CURVES SHOWING PROPORTIONATE RADIATION OF VARIOUS WAVE LENGTHS AT INDICATED TEMPERATURES OF INCANDESCENT SOLID

Every body or material has, however, its own fairly well-marked limiting temperature beyond which, if it is raised, the structure of the body rapidly deteriorates. Carbon, for instance, when heated in vacuum, throws off minute carbon particles very rapidly at temperatures above 1 800 degrees C. This, therefore, is the temperature which limits the efficiency of the carbon filament incandescent lamp. Fortunately, in the case of both gas and incandescent lamp light sources, materials have been found which will withstand high temperatures without rapid deterioration. The gas mantle is too well known to need comment,

FIG. 3—CURVES SHOWING RELATIVE CANDLE-POWER DISTRIBUTION OF TUNGSTEN AND OF CARBON FILAMENT LAMPS AT EQUAL WATTAGE

but at its introduction it marked a tremendous advance in efficiency of light sources. Now a still greater advance has been made by the development of methods of preparation of various metals, of which tungsten stands first, for use as the filament of the incandescent lamp. Tungsten may be

raised in vacuum to a temperature of at least 2 300 degrees C. without the occurrence of rapid deterioration. This increase in temperature from 1 800 to 2 300 degrees C. represents an increase in efficiency of 250 percent.

The relative light distribution of carbon filament and tungsten filament lamps when burning at equal wattage, is shown in Fig. 3. The carbon filament lamp is burning at 3.1 watts per mean horizontal candle, the tungsten filament lamp at 1.25 watts per mean horizontal candle.

TABLE II—ALL VALUES INVOLVING CANDLE-POWER ARE
EXPRESSED IN TERMS OF MEAN SPHERICAL CANDLES

KIND OF LAMP	MEAN SPHERICAL CANDLE-POWER	WATTS PER CANDLE	AMOUNT OF LIGHT PER KW–HR.
Common 56 watt carbon filament incandescent lamp rated at 3.5 watts per candle, 16 horizontal c-p..........	13.2	4.24	236 c-p. hrs.
Common 50 watt carbon filament incandescent lamp rated at 3.1 watts per candle, 16 horizontal c-p..........	13.2	3.78	264 " "
3-glower 264 watt Nernst lamp..........	81.0	3.26	307 " "
High-efficiency Gem 125 watt graphitized carbon filament lamp of 50 horizontal c-p	40.7	3.07	326 " "
44 watt tantalum lamp, 22 rated horizontal c-p.....................................	16.0	2.75	364 " "
Direct-current 5.1 ampere enclosed arc on 110 volt circuit, 0.5 inch carbons..	213.	2.63	380 " "
Alternating-current enclosed 5.7 amp. arc taking 388 watts on 110 volt circuit, 0.5 inch carbons...................	152.	2.55	392 " "
Tungsten 60 watt, 1.25 watts per candle, 110 v. lamp......................	37.0	1.62	641 " "
Luminous 8 amp. arc, 440 watts, 2 in series on 110 volt circuit................	1020.	0.431	2320 " "

Table II shows the efficiency of the tungsten lamp as compared with other electric illuminants.* Values for the tungsten lamps were obtained from tests and are accurate for the type of lamp tested to within + or — 3 percent.

*This table, with the exception of the value for tungsten lamps, is taken from Cravath and Lansingh's "Art of Illumination."

APPLICATION OF AUTOMATIC CONTROLLERS TO DIRECT-CURRENT MOTORS—II

CONTROL OF PUMP MOTORS

D. E. CARPENTER

IN general, the control of motors driving pumps, air compressors, etc., offers a very inviting field for the application of automatic devices. With few exceptions, pumps are employed to maintain regularly varying conditions between fixed limits, whether handling liquids or gases; usually the level or the head of a liquid, or the pressure in a closed tank system is to be maintained. Under such conditions it is seldom feasible to operate the pump continuously, especially if the pumping requirements vary. The preferable method is to provide the system with enough storage capacity to permit the operation of the pump intermittently. This periodical starting and stopping requires either the presence of an attendant or an automatic controlling device.

Electric motors are adopted to automatic control better than any other form of power. A well built motor, with reasonable care, is always ready for operation, will start promptly, requires no warming up, and the process of starting is so unvarying that it can be made entirely automatic. Various automatic starters have been developed for pump motors, nearly all of them having features of merit. Magnet switch starters* are much used for this class of service when the pumps are driven by direct-current motors. The general appearance of a three-point magnet switch starter may be seen by referring to Fig. 1. The control can be made wholly automatic or semi-automatic, the chief difference between the two methods being in the operation of the master switch which governs the action of the controller. The master switch for an automatic controller is operated by the varying level of a liquid or changing pressure of a gas; that for a semi-automatic controller is operated manually. Either type of starter can be operated from a distance; i. e., the master switch need not be near the controller. The starter consists of a group of automatic magnet switches on a suitable panel, with a starting resistance, and with or without auxiliaries such as an accelerating relay, circuit breaker relay, line switch with fuse, etc., according to the requirements and conditions of operation.

*The general features of these switches were described in the JOURNAL for January, 1909.

The automatic master switch is the same whether operated by a float or a pressure regulator, namely a single-pole, double-break switch opening and closing with a quick-snap action. In normal service this switch carries from one and one-half to three amperes and only two small wires are needed to connect it with the starter. The latter can be placed near the motor and pump, its proper location, while the former can be at the tank or, in the case of the pressure type switch, at any other convenient location.

The Float Type Master Switch is attached to the inside of the tank near the top or to some other suitable support above the highest level of the liquid as shown in Fig. 2. A float plays between
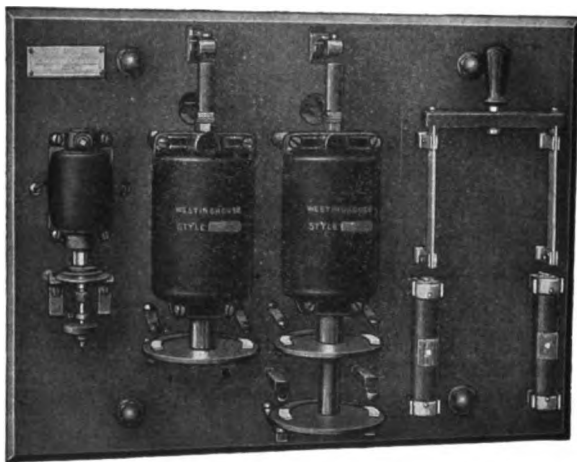
FIG. I—THREE-POINT SEMI-AUTOMATIC PUMP STARTER WITH LINE SWITCH, ENCLOSED FUSES AND ACCELERATING RELAY

metal collars on a vertical rod which operates the switch through a system of levers. An adjustable counterbalance spring compensates for the weights of the different lengths of rod used, and the positions of the collars on the rod can be adjusted for different level limits. The usual length of rod is for a maximum variation of six feet in the water level. When the float rests on the lower collar the switch closes, and when the rising liquid raises the float up against the upper collar the switch opens. The entire mechanism can be mounted inside the tank, only the two small connecting wires passing through the tank walls or cover.

The Pressure Type Master Switch can be mounted at any convenient point where it can be connected by piping to the pressure tank. With this switch is usually supplied a pressure regulator and

a compensating air chamber that assists in giving very close regulation of pressure. The pressure regulator, as shown in Fig. 3, consists of a vertical cylinder containing a movable piston below which is the connection with the pressure tank and the compensating chamber. A rod connects the piston to a weighted lever, and a link

connects the lever to the switch mechanism. The position of the weight on the lever is adjustable for different pressures up to 100 lbs. per square inch, and at pressures between 40 and 100 lbs. per square inch will operate at a variation of not over seven and one-half lbs. either way from the point of adjustment. As the pressure in the tank falls, the weight forces the lever downward until the switch closes; the rising pressure in the tank causes the piston to rise and force the lever upward until the switch snaps open.

FIG. 2—FLOAT TYPE MASTER SWITCH WITH TANK FLOAT

Fig 4 shows the connections, viewed from the rear, of a three-point automatic magnet switch pump starter with a line switch and a float type master switch.

When the water level falls to the lower limit, the master switch closes; switch coil M receives current through the master switch and contacts *3-a-4*, contacts I close, coil M_2 receives current through contacts *9-b-8*, contacts II close, coil M_3 receives current through contacts *7-c-6*,

FIG. 3—PRESSURE TYPE MASTER SWITCH WITH PRESSURE REGULATOR

and contacts III close, the acceleration being by voltage drop in the starting resistance. The last magnet switch to close raises contact *a* from contacts *3-4* and causes it to bridge contacts *1-2*. Opening the circuit at *3-4* cuts off the current from coils M_1 and M_2, and contacts I and II drop open. Bridging contacts *1-2* causes coil M_3 to receive current through a protecting resistance *r*. This protecting resist-

ance minimizes the current consumption in coil M_3, and the coil remains cool while in continuous operation.

When the water level reaches the upper limit the master switch opens and is immediately followed by the opening of contacts *III*, completely disconnecting the motor from the line. With this arrangement contacts *III* are the only ones needing blow-out coils.

The connections of a starter with a pressure regulator are identical with those shown in Fig. 4, except that the operations of the master switch depend on a pressure regulator properly connected by pipes to the pressure tank, instead of being controlled by a float. In order to obtain a steady pressure the regulator should be connected directly to the tank rather than to the discharge pipe from the pump or from the tank. With either of the latter connections the regulator is liable to be affected by pulsations or variations in the pressure.

The connections and operation with a different number of magnet switches as well as the use of an accelerating relay, will be readily understood from the preceding description. It will also be evident that the master switch can be operated manually if preferred. In this case any good snap switch can be used and its location can be made convenient for the operator, without special regard to the location of the starter.
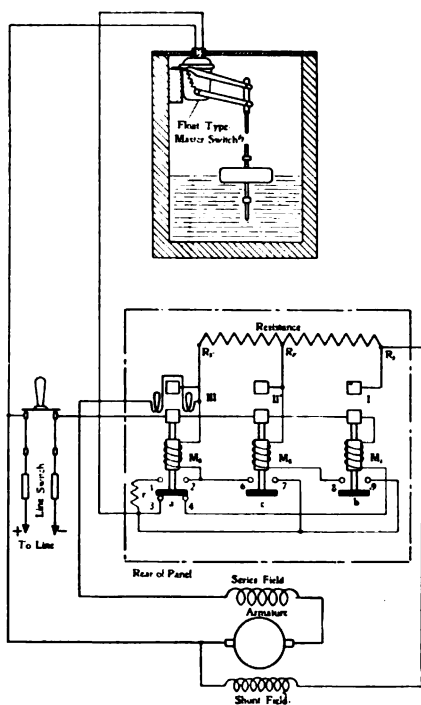
FIG. 4—CONNECTION DIAGRAM FOR THREE-POINT AUTOMATIC PUMP STARTER WITH FLOAT TYPE SWITCH AND FLOAT

Fig. 5 shows a diagram of connections for a three-point starter with a series accelerating relay and a fused line switch. In this case, closing the line switch connects both the shunt field and the armature across the circuit; the shunt field directly and the armature in series with the starting re-

sistance R_1 R_3 and the accelerating relay R. When the motor starts the starting current is sufficient to energize the relay magnet and lift contact a from contacts *1-2*. As the motor accelerates, the starting current decreases until contact a drops and bridges contacts *1-2*. Current then flows from the positive side of the line through the magnet switch coil M_1, contacts *5-b-6*, *11-c-12*, *1-a-2*, to the negative line at n, resulting in the closing of contacts *I*, thereby short-circuiting the section R_1 R_2 of the starting resistance and causing enough increase in the starting current to open again the relay contacts *1-a-2*. When the first magnet switch operates, however, contact c bridges contacts *9* and
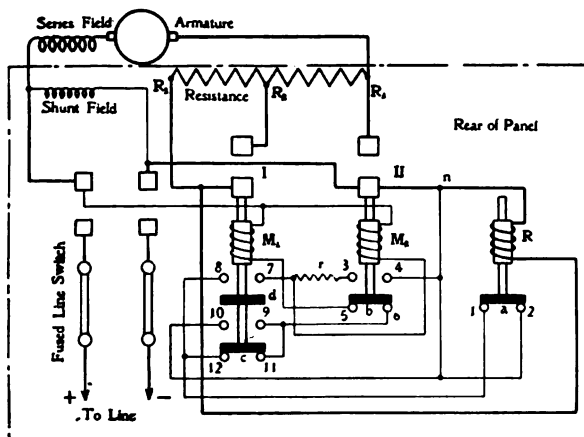
10 so that the circuit through coil M_1 is left intact. At the same time contact d rises and bridges contacts *7* and *8* so that as soon as the r e l a y contacts *1-a-2* close again, the magnet coil M_2 is energized, the path of the current b e i n g through the coil,

FIG. 5—CONNECTION DIAGRAM FOR THREE-POINT SEMI-AUTO-
MATIC PUMP STARTER

the contacts *7-d-* *8* and *1-a-2*, and thence to the negative line at n. Contacts *II* close and short-circuit both the last section of resistance R_2 R_3 and the relay coil. The second magnet switch, in closing contacts *II*, also raises contact b from *5-6* and causes it to bridge contacts *3-4*. The opening of the contact at *5-6* cuts off the current from the magnet coil M_1 and contacts *I* open; bridging the contacts *3-4* connects a protecting resistance r in series with coil M_2 so that the energy used in this coil, the only one used for continuous operation, is reduced to a minimum. Contacts *II* may or may not be provided with blow-out coils according to the conditions of service. Contacts *I* are never required to open a circuit carrying current, and therefore do not need blow-out coils.

METER AND RELAY CONNECTIONS—(Cont.)

SIX-PHASE CIRCUITS

HAROLD W. BROWN

SIX-PHASE circuits are similar in their connections to three-phase, and where a machine is to use six-phase power, it is common practice to transmit it as three-phase. It is therefore possible to connect the meter transformers to the high-tension, three-phase lines, and make three-phase measurements by methods already described; but it is usually preferable to connect to the low-tension six-phase circuit. The following diagrams apply to these six-phase measurements.

Six-phase connections of the main lines may be made between the power transformers and the machine in either of two ways, known as the *double-delta* and the *diametrical* connection.* In the case of the double-delta connection each of the power transformers has two secondary windings; and, as the name implies, there are two distinct delta connections of these secondary circuits. Each delta is made up of one of the two secondary coils of each transformer. There is no connection between the two deltas outside of the machine to which the secondaries are connected. With the diametrical connection the two secondary leads of each transformer are connected to diametrically opposite points in the winding of the machine, with no connections between the secondaries of the three transformers.

DOUBLE-DELTA CONNECTION

Group Including Polyphase Meters—A group of meters is shown in Fig. 1, connected to a six-phase—double-delta-connected circuit. Three lines, A, B, C, are connected to one delta, and the remaining three, A', B', C', to the other delta. The connections between the transformers on A, B, C and the meters are identical with the connections on a three-phase—three-wire circuit. The connections to the *series transformers* on A', B', C', are the same as on A, B, C, reversed; i. e., connections to the upper end of the transformers on A', B' and C' correspond to the connections to the lower end of those on A, B and C, and vice versa. The leads from the transformers on A, B, C, are con-

*For phase relations of double-delta and diametrically-connected circuits, see article on "Vector Diagrams," in the JOURNAL for June, 1908, p. 347.

nected to corresponding leads from those on A', B', C', so that the secondaries of transformers on A and A' are in parallel, and similarly, the secondaries of those on B and B', and those on C and C', respectively, are in parallel. *Shunt transformers* are not required on A', B', C', to correspond with those on A. B, C, because it is assumed that A', B', C', are respectively equal, and exactly opposite in phase, to A, B, C. The reversal of series transformer connections mentioned above is made on account of this opposition of phases. All connections for A', B' and C' are dotted, to distinguish them from those for A, B and C.
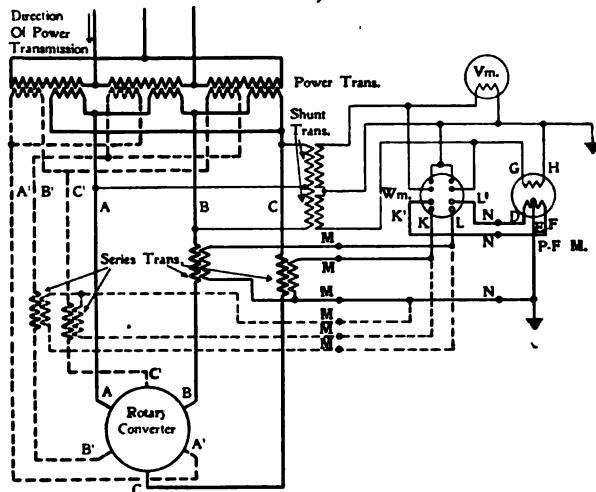
FIG. I—POLYPHASE WATTMETER, THREE-PHASE POWER-FACTOR
METER, AND VOLTMETER ON A SIX-PHASE—DOUBLE-DELTA
CIRCUIT
Ammeters may be inserted at M or N. If the power-factor meter is omitted, D, E and F should be connected together. If the wattmeter is omitted, K should be connected to K' and L to L'. All of these diagrams show rear view connections to the meters and relays.

Six ammeters or ammeter receptacles may be inserted at the points M to measure the current on each line, or three may be inserted at N, each to measure the sum of the currents on two corresponding lines. If the power-factor meter is omitted, all the lines, D, E, F, should be connected together. If the wattmeter is omitted, K' should be connected to K, and L' to L. If the pointer of the power-factor meter rotates in the counterclockwise direction* when only the series connections are made,

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*This is discussed more fully with reference to Fig. 5, in the article on "Three-Phase—Three-Wire Circuits" in the JOURNAL for December, 1908, Vol. V., pp. 729-730.

the series connections D and E should be interchanged; also, the shunt connections, G and H should be interchanged.

Single-Phase Meters — Balanced Circuit — If a six-phase—double-delta-connected circuit is balanced, single-phase meters may be used as in Fig. 2. These meters are connected to only one delta, and the arrangement is identical with that for connecting single-phase meters to a three-phase—three-wire circuit. The ammeter measures the current in one line, and the wattmeter, the power transmitted by one delta circuit. The total power is therefore twice that indicated by the wattmeter. The power-factor meter indicates the power-factor of one delta, and therefore of the entire system, inasmuch as the load is balanced. The voltmeter in both Figs. 1 and 2 measures the e.m.f. between two lines of the same delta. The ratio of this e.m.f. to the e.m.f.'s between the three-phase lines is .the same as the ratio of transformation of the power transformers. The e.m.f. between these lines of the six-phase circuit is about 0.61 ($=$0.866 $\times$ 0.707) of the direct-current e.m.f. of the rotary converter.
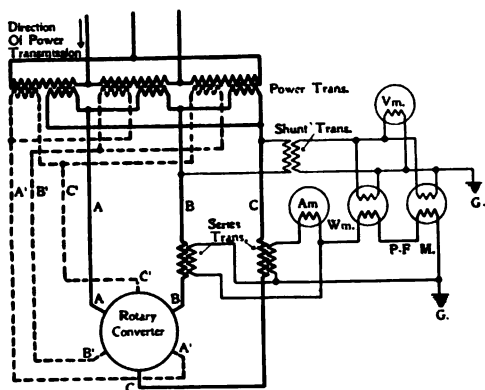
FIG. 2—SINGLE-PHASE METERS ON A SIX-PHASE—DOUBLE-DELTA CIRCUIT

The wattmeter measures one-half of the power, and the power-factor meter the true power-factor if the circuit is balanced. The ammeter measures the current in one line.

Single-Phase Meters—Unbalanced Circuit—If the circuit is liable to be unbalanced, a single-phase wattmeter or power-factor meter may be connected as in Fig. 3 to measure the power or power-factor of one line at a time, using voltmeter and ammeter receptacles. There are three positions for the voltmeter plug, and six for the ammeter plug, *i. e.*, three for each delta. The ammeter receptacles at the top are for the A, B, C delta and those at the bottom for the A', B', C' delta. When the voltmeter plug is in the left, middle or right hand position, the ammeter plug should likewise be in the left, middle or right hand ammeter receptacle of either delta in order to give the proper phase relations for the measurement of power or power-factor. Four series and two shunt transformers are shown in this diagram. Such an arrangement is suit-

able for use only where the machine to which the six-phase circuit is connected is a rotary converter, or where the two delta-connected circuits have a common neutral point. The wattmeter indicates twice the actual power transmitted by each line (*i. e.,* one-third of the total power transmitted if the load is balanced), unless special series transformers or a special calibration of the wattmeter is provided.

The currents from the series transformers on lines *A* and *C,* flow respectively through the upper left and right hand receptacles. The current in *B* is the same as the resultant of *A* and *C,* but in the opposite direction. The resultant of these two trans-
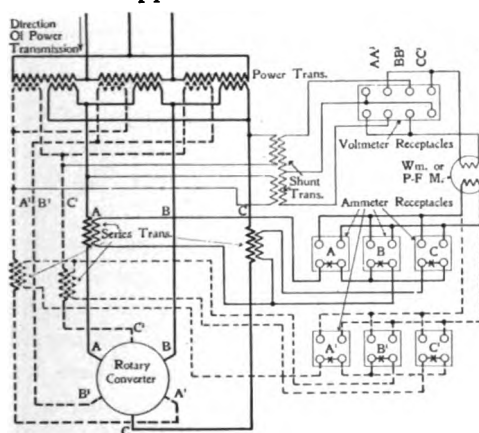
FIG. 3—SINGLE-PHASE WATTMETER OR POWER-FACTOR METER ON DOUBLE-DELTA—SIX-PHASE CIRCUIT

Used only where the two deltas are interconnected, through a rotary converter or otherwise, so as to have a common neutral.
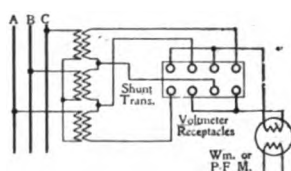
FIG. 4—VOLTAGE CONNECTIONS FOR USE IN PLACE OF THOSE IN FIG. 3 WHERE THE TWO DELTAS ARE INDEPENDENT.

Current connections are as in Fig. 3.

former currents flows through the upper middle receptacle. If the currents in receptacles *A* and *C* are considered as flowing to the right, the current in receptacle *B* must be considered as flowing to the left, because it is the *negative* of the resultant of the other two. The current connections for *A'*, *B'*, *C'* are the same as for *A*, *B*, *C*, except that the upper series transformer connections on *A'*, *B'*, and *C'* correspond respectively to the lower connections on *A*, *B*, *C*, and vice versa. This gives the right phase relation to the voltage circuits.

The shunt transformers are connected between *A* and *A'*, and between *C* and *C'*. When the voltmeter plug is in the left hand position it connnects the meter to *A* and *A'*, and in the right

hand position, to C and C'. In the middle position the e.m.f. on the meter is the resultant of AA' and CC', which is the reverse of BB', if the e.m.f.'s are balanced.* The current connections for the middle receptacles are reversed to correspond to this reversal of e.m.f. If the two deltas of the six-phase circuit are insulated from each other (as might be the case if the rotary converter were replaced by a synchronous motor), three Y-connected shunt transformers are required. The connections between shunt transformers, receptacles, and the voltage circuit of the meter must then be as shown in Fig. 4; the series connections are as in Fig. 3.

FIG. 5—DOUBLE-Z-CONNECTED OVERLOAD, INVERSE TIME LIMIT RELAYS FOR SHUNT TRIPPING ON SIX-PHASE—DOUBLE-DELTA CIRCUIT

Relays—Overload relays may have a double Z-connection as in Fig. 5 or Fig. 6. In the former the relays are arranged for shunt tripping, and in the latter for series tripping. In case *shunt tripping* is employed, there is no reason for having a large current in the common return line; in fact, the smaller the current in this line the less the load on the transformer. For this reason, in Fig. 5, the transformers on A', B', C' are connected to correspond to those on A, B, C. With a balanced load, A neutralizes A', B neutralizes B', and C neutralizes C' so that there is *no current flowing in the common return line*. But with *series tripping* there must always be sufficient current in one or the other of the trip coils to operate it, in case of an overload. The transformers on A', B', C', in Fig. 6, are therefore connected in *opposition* to those on A, B, C. If there is an overload on the lines such that either of the relays marked R_1 operates, the current from that relay flows through the trip coil T_1, while if one of those marked R_2 operates, the current flows through T_2. Both T_1 *and* T_2 are on the same circuit breaker, so that if a current flows through either of them the circuit is opened.

**See footnote, p. 172.

Reverse-current relays may be connected to a double-delta-connected—six-phase circuit as in Fig. 7. Only two shunt transformers are required to provide e.m.f.'s having all the required phase relations. These transformers are V-connected, and the left hand voltage terminals of the relays A, B, C are connected to the three leads from the shunt transformers. The three right hand voltage terminals are connected together so that the voltage circuits of these three relays are Y-connected. The relays A', B', C', are connected in exactly the same manner to these same shunt transformers. In order to protect against reverse current in any one of the lines it is necessary to provide six series transformers. One lead of each transformer is connected to the common return
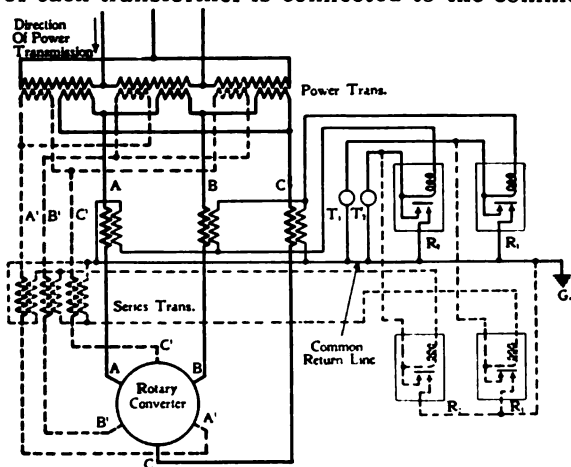
FIG. 6—DOUBLE-Z-CONNECTED OVERLOAD INVERSE TIME LIMIT
RELAYS FOR SERIES TRIPPING ON SIX-PHASE—DOUBLE-
DELTA CIRCUIT
$T =$ Trip Coils of Circuit Breakers. $R =$ Relays.

line, and the right hand current terminal of each relay connects to this return line. The other lead of each transformer connects separately to the left hand current terminal of one of the relays, so that each relay protects one of the lines against reverse current. The lower ends of the series transformers A, B, C connect to the common return line, and the upper end of transformers A', B', C' connect to this line. By this reversal the currents in the relays A', B', C' have the right phase relation to the corresponding e.m.f.'s.

DIAMETRICAL CONNECTION

Group Including Polyphase Meters—Fig. 8 is a group of meters on a diametrically-connected—six-phase circuit. Two shunt and

three series transformers are required. One of the shunt trans-
formers is connected across AA' and one across CC'. The sec-
ondaries of the series transformers are delta-connected. Con-
sidering these series transformers separately, the current on line
A reacts in the wattmeter with the e.m.f. across AA', and that
one line C reacts with the e.m.f. across CC'. The current from the
series transformer on B flows through *both sides of the wattmeter*,
and thus reacts with the resultant of the two e.m.f's AA' and CC',
which is equivalent to the e.m.f. BB' in the reverse direction, if
the e.m.f.'s are balanced. The reaction of each of the currents
with its e.m.f. is such as to produce a positive reading, so that the
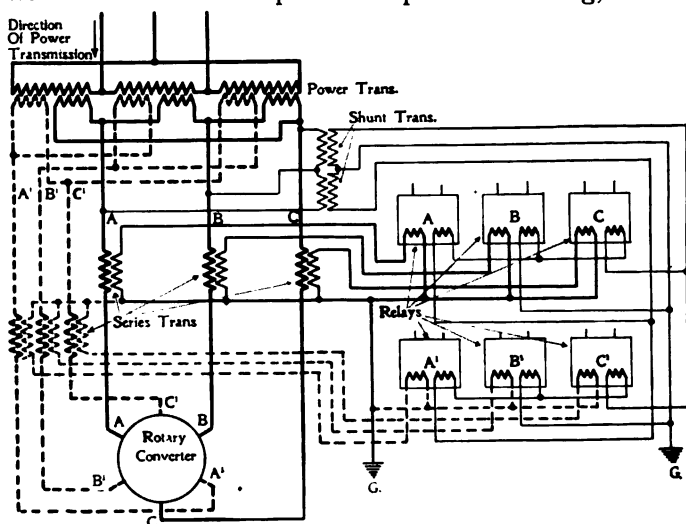
FIG. 7—REVERSE-CURRENT RELAYS ON SIX-PHASE—DOUBLE-DELTA CIRCUIT
Connections to the contacts, which are brought out at the top of the
relays, are omitted for simplicity.

indication on the wattmeter is the total power transmitted by the
six lines, comprising three circuits. The power-factor meter in-
dicates the mean power-factor for the entire circuit. These con-
nections are similar to those for a three-phase—four-wire cir-
cuit; the only difference being that, instead of connecting from
one line to neutral, for a six-phase—diametrically-connected cir-
cuit the shunt transformers are connected between the two lines
from one power transformer. The e.m.f. is twice as much in this
case as where the connection is to neutral.

Variations of e.m.f. due to unequal drop in the lines of the
three-phase part of the system represented in Fig. 8 produce corre-

sponding variations on the secondary voltage circuits*; *i. e.,* the e.m.f.'s across *RT, RS* and *TS* are proportional respectively to the e.m.f.'s across *AA', BB'* and *CC',* if there is no unbalancing due to drop in the six-phase part of the system. But if there are variations in the drop in the secondaries of the power trans-formers or in the *six-phase* lines, such unbalancing is not repro-duced in variations in the secondary voltage across *SR.* The effect of this unbalancing on the wattmeter reading is negligible in all ordinary cases, for the e.m.f.'s across *RT* and *ST* are correct in any case, and the third e.m.f. usually varies about the same amount as the other two.

Only three ammeters or ammeter receptacles are required for measuring the current on each line of a six-phase—diametrically-connected circuit, be-cause the two lines con-necting the same power transformer must carry the same current, ex-cept in case of an acci-dental ground or short-circuit. These ammeters or receptacles may be in-serted at the points marked *M* in Fig. 8.

If the wattmeter or power-factor meter is omitted, or if the power-factor meter rotates in the wrong direction, the same changes in connec-tions should be made as

FIG. 8—POLYPHASE WATTMETER, THREE-PHASE POWER-FACTOR METER, AND VOLTMETER AND SIX-PHASE—DIAMETRICALLY-CONNECTED CIRCUIT

Ammeters may be connected at *M.* If the power-factor meter or wattmeter is omitted, the same changes should be made as those in-dicated for similar conditions in connection with Fig. 1.

referred to in the foregoing discussion of the double-delta-connected circuit. If shunt transformers are not required on account of the low voltage of the rotary converter, the lines *C* and *C'* should con-nect to the power-factor meter and to the right hand side of the wattmeter (as shown in the diagram, but with the shunt transform-ers omitted), but a separate line should connect *A* to the upper left hand terminal of the wattmeter, because, otherwise, there would be a short-circuit between *A* and *C'.*

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*This is true because, on the three-phase side, the power transformers are delta-connected, and one e.m.f. is therefore the same as the resultant of the other two.

Single-Phase Meters—Balanced Circuit—The connections of single-phase meters on a balanced diametrically-connected circuit are shown in Fig. 9. Each meter makes measurements on the lines from one power transformer. The power on the entire system is three times that indicated by the wattmeter. The ratio of the e.m.f. on the shunt transformer to that on the three-phase circuit is, of course, the ratio of transformation of the power transformers. As the shunt transformer is connected to diametrically opposite points on the rotary converter, it has an e.m.f. which is 0.707 of the direct-current e.m.f. If it is desired to make measurements on each line separately, plugging connections may be made as in Fig. 3,* omitting the connections shown dotted; *i. e.*, connecting to series transformers on *A*, *B* and *C*, but

FIG. 9—AMMETER, VOLTMETER, AND SINGLE-PHASE WATTMETER AND POWER-FACTOR METER ON BALANCED SIX-PHASE — DIAMETRICALLY-CONNECTED CIRCUIT

The wattmeter and power-factor meter measure the power, and power-factor, respectively, of one pair of lines. For condition of balanced load, the wattmeter reading may be multiplied by 3 for total power.

omitting those on *A'*, *B'* and *C'*. One of the shunt transformers should be connected between *A* and *A'* and the other between *C* and *C'* as in Fig. 3.

Relays — Overload relays may be connected to a diametrically-connected circuit in the same manner as in Figs. 5 and 6.* If no protection against short-circuits in the six-phase part of the system is desired, the lower relays and the dotted connections may be omitted, since the currents in these relays are the same as those in the upper two (except in case of a short-circuit).

Reverse current relays may be connected to a diametrically-connected circuit as in Fig. 7.* If it is not required to protect against reverse currents due to short-circuits in the six-phase part of the system, the relays on *A'*, *B'*, *C'* may be omitted. An-

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*As shown in Figs. 3, 5, 6 and 7, the power transformers are double-delta-connected. In the application of these diagrams to a diametrical connection, the lines *A*, *B*, *C*, *A'*, *B'* and *C'* are differently connected to the power transformers; but they are connected to the rotary converter in the same order as in Figs. 8 and 9. The phase relations of these lines are therefore the same with the double delta as with the diametrical connection.

other possible arrangement of voltage circuits of these relays is to bring both leads of each relay directly to the shunt transformers. The connections from the primaries of the shunt transformers to the main lines should then be as in Fig. 3, in order to give exactly the right phase relation between current and e.m.f. If the primary circuits *AA'*, *BB'* and *CC'* are insulated from each other, as may be the case if the machine is a synchronous motor, this arrangement is necessary, in order to complete the primary circuits of the shunt transformers correctly; but with a rotary converter, either arrangement is effective.

GENERAL

The present paper has omitted reference to some connections considered in previous articles, which would be suitable for six-phase circuits. It will be found in general that three-phase—three-wire connections may be adapted to six-phase—double-delta-connected circuits by duplicating the connections for one delta. A six-phase diametrically-connected circuit may be treated in much the same way as a three-phase—four-wire circuit; in fact, a three-phase—four-wire, Y-connected circuit may be considered as a six-phase circuit in which the currents in three of the phases are *combined in the neutral line*. From another point of view, the diametrically-connected system may also be considered as a combination of three single-phase circuits, just as a two-phase system is a combination of two single-phase circuits.

EXPERIENCE ON THE ROAD

VOLTAGE DROP BETWEEN RAILS AND WATER PIPE SYSTEM

C. W. KINNEY

During some recent tests to determine the potential difference between a water pipe system and the rails of an electric railway, it was desired to approximate the amount of current flowing in the pipe itself. The instruments available were an ammeter and a 600 volt voltmeter with a low reading calibration terminal. The determination was made as follows:—The water pipe was exposed for about six feet of its length. Three places on the pipe, two and one-half feet apart, were filed bright and the drop in voltage, as indicated by the voltmeter, between the first and second points and then between the second and third points was noted. After these readings had been taken, an ammeter reading was taken between the rail and the middle point on the water pipe. While the ammeter was still connected, voltmeter readings were taken as before. The voltage drop between points *1* and *2* showed less than one-half of one percent of the original value. Thus the voltage drop between points *2* and *3* could be assumed to be due entirely to the current flowing through the ammeter. The normal flow of current in the pipe was then calculated by a simple proportion; that is, the current flow during the first test bore the same relation to the ammeter reading that the voltmeter throw between points *2* and *3* during the first test bore to the throw of the voltmeter needle when the ammeter was connected, since the voltmeter was of the uniform scale type. It was, therefore, not necessary to determine the actual value of the divisions on the voltmeter scale in order to find the amount of current flowing in the pipe.

TROUBLES INCIDENT TO THE PARALLEL OPERATION OF TWO-PHASE INTER-CONNECTED GENERATORS

The following experience is a good example of the confusing results sometimes attendant upon the operation of two-phase inter-connected generators in parallel. There were two composite-wound, two-phase, 240-volt generators operated in parallel, one of 100 kw capacity, and the other a 75 kw machine. These generators were belt-connected to the same counter-shaft, and were of like characteristics. After two years of satisfactory and uninterrupted service, the circuit breakers began to trip at irregular intervals. For eight or ten weeks the owners had little difficulty in re-synchronizing the ma-

chines and getting them to take their proportion of the load. Finally, however, conditions became worse and this could not be done successfully, and the services of an expert were requested.

After re-adjusting the composite windings the machines again took their respective loads and the owner furnished a letter stating that the machines were in satisfactory condition. After two days the trouble re-appeared and the same engineer was again called in. It was suggested that the friction clutch between the sections of the driving shaft be bolted fast; the idea being that the clutch was not reliable. When the bolts had been duly tightened, the trouble again disappeared, but only to re-appear again the following day. Subsequent investigations showed a permanently unbalanced condition of the phases on one of the generators. It was then found that this unbalancing could be shifted from one machine to the other by advancing the phases of either machine or by reversing the armature leads, the extent of the unbalancing being dependent upon the character of the changes made. The composite windings were repeatedly checked, the brushes being placed in every possible position, and the commutator short-circuited with the brushes raised. The armature and field windings were tested for grounds, open-circuits and high resistance connections but without successful results. The switchboard, instruments, cables, motors, etc., were all examined, but no trouble could be found. The owner was requested to let the engineer have the use of the machine for a period sufficient to permit an investigation of the two armatures. This was not possible, as the operation of the plant was dependent upon the machines.

The fact that the machines, when operating alone, balanced their loads perfectly and that the unbalanced condition was apparent only at such times as the generators were in parallel, rendered it impossible to tell which machine was responsible for the trouble. Again, as the unbalancing could be transferred from the instruments of one machine to the instruments of the other, the situation became more confusing. After seven weeks of investigation, (the machines were available on Sunday only), it was decided that the difficulty originated in excessive overloads which resulted in temperatures high enough to melt the solder in one or more of the armature connections, thus causing the solder to run and resulting in high resistance connections or a temporary open circuit. Currents large enough to trip the circuit breakers would then flow between the machines. When the machines were relieved of their loads the

solder would set and during the time required for re-synchronizing would again harden and the trouble would disappear.

To prove this theory the machines were frequently brought to a stop after operating under loads and each armature connection carefully examined for high temperature, but without results, as the solder was cooled by the fanning of the machines while being brought to a standstill.

A year elapsed during which time an additional machine was installed and the two machines which had been giving trouble were turned over to the engineer. It was found that the solder had long since ceased to serve its purpose and that an open circuit in the armature of the 100 kw generator had resulted. A heavy current was then sent through the windings with the armature at a standstill, and in a short time a second defective connection of high resistance was located directly opposite the open-circuited coil. These connections were properly made and the machines again placed in service.

It may be seen that while resistance tests on the windings of these machines were misleading, the passing of a heavy current through the windings with the armature at rest promptly located the trouble, and it is quite possible that if this method had been employed in the beginning, the real difficulty might have been located at a much earlier date. It is evident that the use of heavy currents in locating weak or high resistance connections in windings of any nature results in much more conclusive evidence than the usual method of measuring resistance.

THE JOURNAL QUESTION BOX

220—EMERGENCY STARTER FOR INDUCTION MOTOR—Please suggest method of starting two-phase and three-phase induction motors that have had their auto-transformers burned out. It is desired to keep the installation of motors in service while the transformers are being sent to the factory for repairs.   H. M'E.

By connecting separate *equal* resistances in the primary circuit, of sufficient amount and capacity to cut down the voltage and thereby limit the primary current, the motors can be started without difficulty. The amount of the resistance would probably have to be determined by experiment and, this being done, a short-circuiting switch should be provided to short-circuit these resistances after starting. A practicable method might be to construct a simple water rheostat for each line of the three-phase or two-phase circuit, as the case might be. Various suggestions for such rheostat have appeared in previous issues of the JOURNAL. See for example, the "Experience on the Road" articles in the issues for January, 1909, November, 1908, and November, 1907. G. H. G.

221—SKIN EFFECT—Given two copper conductors, each of equal area (say 1 000 000 circ. mils.), one stranded and the other solid, will the skin effect be practically the same in each or will it be considerably less in the former because of its being stranded, assuming 60 cycles as a frequency? Please give the equation by means of which the skin effect factor may be calculated in each case.   T. C.

Theoretically the skin effect would be greater in a concentric stranded cable because of its greater diameter for given area. If the cable were made up of several smaller stranded cables each of these being composed of conductors insulated from one another, the effect of the arrangement would be that of transposing the respective conductors, relative to the center of the whole cable, and in such a case the skin effect would probably be reduced, for a given total diameter. Practically, however, the difference in conductivity of the two cables considered would be so small as to be negligible. Regarding equations for calculating skin effect, information regarding this subject may be obtained by reference to the various handbooks for electrical engineers, which give tables and simple methods of calculating the increase in resistance of a conductor to alternating-current over the specific resistance offered to direct-current.
          H. M. S.

222—SPECIAL WATTMETER CONNECTIONS—The accompanying diagram of connections, Fig. 222 (a), gives what seems to be a new method of wattmeter connection, which is used by a local power company. It does not record the power correctly, however, although the meters have been checked. Two single-phase wattmeters are used. The series transformers are on the neutral side of the high-tension windings of the power transformers and have a ratio of 3 to 1 with 5 ampere secondaries. The potential for the voltage coils of the meters is obtained from an auto-transformer connected across two of the three secondary phases, the ratio being 375 to 110 volts. The load on the

power transformers is 125 kw. Please explain why the meters run slow and why one records twenty times as much power as the other. W. E. C.

The current in the left hand meter is proportional to and in phase with that in line *a*, and the e.m.f. across the voltage circuit of this meter corresponds to that between *a* and *b*. The current in the right hand meter corresponds to that in *b*, and the e.m.f. corresponds to that between *b* and *c*. *These connections are wrong*—In order to indicate the total power transmitted, the current in the right hand meter should correspond to that in line *c* (which has
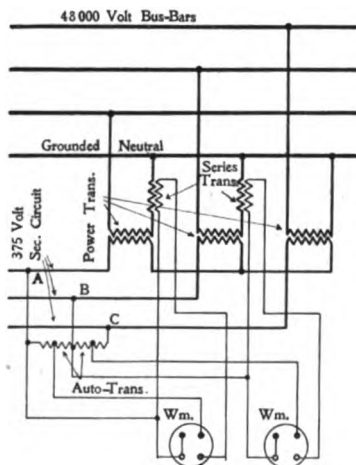
FIG. 222. (a)

no voltage connection to the other meter), *i. e.*, the right hand series transformer should be in series with the right hand, instead of the middle, power transformer. The voltage connections to the right hand meter should connect to the auto-transformer between *b* and *c* (as shown in the diagram), but the connections should be *reversed*. The readings on the two wattmeters will not be equal, except in case of 100 percent power-factor, even with a balanced load. A slight error in phase relations is introduced by having the series transformers on the high-tension side. A more accurate method of connecting would be to have the series transformers on the low-tension lines, *a* and *c*. H. W. B.

223—R E P A I R I N G SQUIRREL-CAGE WOUND INDUCTION MOTOR — What is the best way to unsolder and sweat in again the bars on an induction motor of the squirrel-cage type in which there are four short-circuiting rings at each end of the rotor? The machine in question is a 30 hp. motor on which it is necessary to make repairs, as the insulation has been impaired by moisture, thus causing the motor to "pull out" and unduly heat the rotor. At times it will not pull its load nor even start up. G. K. M.

It is possible to melt the solder on such a piece of apparatus by means of a blow torch such as is commonly used by electricians, repairmen and linemen. If the insulation is not seriously damaged it may possibly be feasible to dry it out by running the motor steadily on reduced voltage; for example, by introducing sufficient resistance in the primary circuit to cut down the primary voltage and thereby limit the current. Another method of drying out insulation is to inclose the motor in a large box into which hot dry air is forced. Either process of drying should be continued for two or three days, or until the motor insulation is thoroughly dried without burning. When the motor performance is normal, this may be taken as a general indication that the insulation is again in good shape. In this connection refer to No. 122 in the August, 1908 issue. G. H. G.

224—TELEPHONE RINGING CIRCUIT TROUBLES—On a telephone system with twenty-two telephones in parallel, the apparatus has been operating satisfactorily for two years, but recently the bells have all been ringing poorly without any changes having been made in the apparatus or circuits. There are no grounds and all contacts have been found to be in good condition. A complete metallic circuit is used. It is my opinion that the permanent magnets of the generator are getting weaker and thereby reducing the voltage

on the circuit. If this is possible how may the magnetism of the permanent U-magnets be restored to its proper strength?   M. T. C.

It is entirely possible for the permanent magnets to lose their strength. If this has occurred, it is probably due to one of the following causes: 1. Faulty work in their manufacture. Either a poor quality of steel used for making them, or carelessness in hardening or magnetizing them. 2. A heavy sharp blow to the magnets such as would occur if the generator were dropped on the floor. 3. The result of coming under the influence of a strong electromagnet; *e. g.*, there might be a generator or a motor near, with a strong field. 4. A partial magnetic short-circuit caused by one or more pieces of iron or steel close to the generator forming part of a magnetic path between the poles of the magnets. Loose screws, nuts, etc., near a magnet tend to collect across the magnetic poles. Similarly, iron-filings tend to work in between the pole pieces and the armature, frequently doing much damage.

If the magnets have been weakened by a blow or by coming near an electro-magnet, they will need to be re-magnetized. For this it would probably be necessary to send the generator to a factory, for example, where generators are made, and where a very strong electro-magnet is available. This and some skill also are required to properly charge the magnets. If it is a partial magnetic short-circuit, it is merely necessary to remove the iron filings or whatever may be giving the trouble. Care should be taken to see that the contacts are all in good shape. If possible it would be well to test the line as follows: Disconnect the wires from the generator and connect them on another strong generator of not too high voltage. If the bells still work badly, examine the line for increased resistance, as, for example, a faulty fuse at the "exchange" end of the line. If, however, the bells ring satisfactorily, examine again all contacts on the generator. A spring contact that is not very stiff or that is somewhat tarnished might be the cause of the

trouble. Or it might be that the insulation on one of the wires in the armature is worn partly through. Part of the winding on the armature may be short-circuited in that way. If in any way there is a high resistance in series with the generator, it might cause the trouble mentioned. In case there is such a resistance in the generator, it may exist only while the armature is in motion; such, for example, as an intermittent open-circuit due to a broken wire which would perhaps be thrown into poor contact by the rotation of the armature of the generator.   C. G. B.

·225—SINGLE-PHASE POWER FROM TWO-PHASE CIRCUITS — Is it possible to operate the secondaries of two standard transformers in parallel when their primaries are connected to the two phases of a two-phase—three-wire system? If so, please give diagram of connections.   J. R. R.

It is impossible to transform from two-phase to single-phase by means of static transformation with balanced conditions. The demonstration of a parallel case for three-
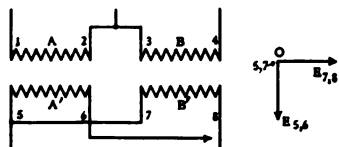
F'G. 225 (a)   FIG. 225 (b)

phase — single-phase transformation was given by Mr. Chas. F. Scott in the JOURNAL for January, 1906, p. 43. The result of the secondary multiple connection such as is suggested in the question would be to short-circuit a voltage equal to 1.41 times the normal voltage across the secondary of one of the transformers in question because of the phase relations between the two secondary voltages. This will be evident from the following: The connections are shown in Fig. 225 (a), in which A' and B' are the secondaries of the two transformers. In the vector diagram, Fig. 225 (b), the center O is taken as the potential of one side of the two secondaries, 5 and 7, which are, ac-

cording to the assumption, connected together and therefore are of the same potential. It is proposed, now, to connect the other two sides, *6* and *8* of the two secondaries, together. The outside wires of the primaries, *1* and *4*, are, because of the two-phase relations, at a difference of potential of 1.41 times the voltage across either phase, *i. e.*, the voltages of the two phases are at an angle of 45 degrees. Hence, the secondary voltages bear the same relation to each other. The voltage relations in the secondaries are indicated in the vector diagram. It is thus apparent that to connect terminal 6 with terminal *8* when *5* and *7* are connected, would be to short-circuit a voltage represented by a line joining the points E_3, and E_7,

226—RELATIVE DIELECTRIC STRENGTH AND ARC-QUENCHING POWER OF OIL AND AIR—What are the relative dielectric strengths of oil and air, *i. e.*, with an oil-filled spark gap of say one inch, what would be the equivalent air spark gap? When abnormal voltage causes a spark to pass an oil gap, to what extent will an arc hold when the voltage has fallen below the point at which the breakdown occurred? H. F. S.

With rounded electrodes of about 0.5 in. diameter a gap of one inch, in good transformer oil, has been found to withstand voltages between 70 000 and 100 000 volts (effective voltage). In air, gaps of 6 to 9.5 in., depending on shape of terminals, etc., would correspond to the above voltages. It is probable that no fixed ratio exists between the dielectric strengths of oil and of air, as the ratio between equivalent spark gaps is different for different voltages. This is due to the different charac-ter of the discharges taking place before the final spark due to "ioni-zation" of the air. As very little is known about the characteristics of an arc burning under oil, it is not possible to state exactly to what extent such an arc will hold when the voltage is lowered. This will also depend on other circumstances such as conditions under which the arc is formed, the characteristics of the electric circuit feeding it, etc. It is

rare in practice that conditions are such that an arc continues for any length of time under oil. O. S. B.

227—DYNAMIC BRAKING ON INDUC-TION MOTORS—Is it possible to secure dynamic braking action on an ordinary slip-ring poly-phase induction motor operat-ing a hoist, similar to the ac-tion obtained in a shunt motor by throwing the armature on the resistance and leaving the field excited? With our present arrangement, it is necessary to do all of the braking by means of the brake shoes, which, as a result, wear less than half as long as on a similar hoist with shunt motor drive. H. A. F.

Yes, it is possible to secure dyna-mic braking action on a polyphase induction motor with phase-wound secondary in the following way:

Leaving the primary of the motor connected to the line, the action of the load will tend to drive the mo-tor backward, *i. e.*, in the reverse direction of rotation to that which it would naturally have in raising the load. An amount of resistance is inserted in the rotor circuit some-what greater than that required to allow the motor to start the load and raise it. If the brake now be removed, the load will begin to lower and the braking torque on the motor will increase until, at a given speed perhaps one-fourth or one-third of the normal hoisting speed, the torque due to the lowering of the load, and that due to the brak-ing effect on the motor will be in a state of balance and the load will then descend steadily at that speed. As this braking speed depends on the amount of resistance inserted, the latter can be varied until the de-sired result is obtained. This action can be best understood from consid-eration of the speed-torque curves given in the JOURNAL for July, 1908, p. 374. It will be noticed that the maximum torque point, which in the case given is 900 pounds, occurs at 500 r.p.m. with the secondary short-circuited, but occurs at 300 r.p.m. with the resistance for the sixth notch inserted and finally the torque at 0 r.p.m. on the fifth notch. It should be understood that these curves do not end at the zero speed

line, but continue on below if the motor is driven backward by the load. Thus, for instance, it may be said that, with the resistance for the fourth notch in circuit, the motor will have to be driven backward at a negative speed of about 300 r.p.m. before it develops the same maximum torque of 900 pounds. As a concrete case assume that the motor represented by the set of curves referred to above is hoisting a load which required 500 pounds torque to hold it in suspension. If now the controller is thrown on the second notch the motor will develop about 440 pounds torque which is not sufficient to hold the load. The motor will, therefore, be driven backward until at a speed of about 100 r.p.m. the motor torque for the second notch will cross the 500-pound line and the load will then descend steadily at a speed corresponding to 100 r. p. m. on the motor. Great caution should be exercised to get the proper amount of resistance, as the motor is liable to "pull out" when running as a brake, in the same manner as when running on heavy load as a motor, because the braking action increases up to the maximum torque of the motor and then decreases if the speed is rapidly increased. In this event the load would be liable to run away with the motor, resulting in serious damage. A. M. D.

228—STARTING MERCURY VAPOR LAMP—Please suggest what might be the trouble with a mercury vapor lamp which requires some twenty minutes of manipulation in order to start it. The lamp is operated on a 60-cycle, alternating-current circuit, and is hand-tilted.
C. R. F.

Either a condition of too poor vacuum in the lamp or too low temperature will cause the lamp to start with difficulty. For example, if the lamp is operated in a room where there is no artificial means of heating it will not start as readily as in a room in which the temperature is perhaps 60 degrees F. or more. If the trouble is due to low vacuum, there is no remedy other than such attention as could be given by the manufacturers. R. P. J.

229—DETERMINING PHASES FOR SYNCHRONIZING—What is the simplest way to phase out a generator to be synchronized with a transmission line?
G. A. R.

A simple method is given in No. 157 in the October, 1908, issue.

230—HUNTING IN ROTARY CONVERTER—We have attempted to use the alternating-current side of a 150 kw rotary converter for lighting purposes, by running it from the direct-current side on 500 volts. This proved satisfactory except that the speed was unstable. It would continually vary from 1 500 r.p.m. to 900 r.p.m. Please explain the probable trouble and suggest a remedy.
E. W. R.

See No. 55 in the May, 1908, issue for hunting of rotary converters. If the alternating-current load on the machine in question includes synchronous motors as well as lighting, the explanation given therein may apply. If, however, the load is purely lighting load the unstable speed conditions may be found to be due to the fact that the brushes are not properly located. In this case a slight shifting of the brushes in order to place them exactly on the neutral point may be found to remedy the difficulty. Hunting is, of course, due to unstable field conditions, which may result from various causes. Hence, in this case it may be found that the trouble can be reduced by strengthening the field without this having a serious effect on the alternating-current lighting load. See also "Hunting in Rotary Converters" by Mr. F. D. Newbury in the JOURNAL for June, 1904, p. 275.
J. B. W.

231—ELECTROSTATIC CAPACITY OF CABLES—Please give a formula and the method of calculation for determining the electrostatic capacity of three-conductor, lead-sheathed cables, i. e., the capacity between one conductor and the sheath, and likewise, between all of the conductors and the sheath as well as the capacity between the conductors. Is the effective

capacity that between any two conductors or between a conductor and the sheath? Please give also the value of specific inductive capacity of rubber, paper and varnished cambric insulations such as commonly used on high-tension cables.

R. H. R.

The usual method for measuring the capacity of three-conductor cables is that known as the discharge-deflection method. By this plan the discharge from a condenser of known capacity is compared with that from the cable, and the capacity of the cable is equal to the capacity of the condenser multiplied by the discharge deflection of the cable and divided by the discharge deflection of the condenser. This method gives capacities which are higher than the true capacities, depending upon the amount of electric absorption of the cable. A better plan is to employ a Wheatstone bridge method where the capacity of the cable is compared with that of a standard condenser by means of two adjustable resistances, an alternating current being used in place of the customary direct- current and a telephone, or vibration galvanometer, instead of the usual galvanometer.

The formula for calculating the capacity of a three-conductor cable is too complicated to be used in ordinary work. As the capacities of these cables vary considerably from time to time, the best plan for getting approximate results is to figure the capacity of a single-conductor cable having a thickness of insulation equal to that between the conductor and the lead sheath of the three-conductor cable. The value thus obtained will probably be found to be near enough for ordinary purposes. The capacity, as thus found, of a three-conductor cable will be that between one conductor and the other two conductors connected to the lead.

The specific inductive capacity of varnished cloth insulated cables varies from about 3.5 to 10 or 12, depending upon the kind of cloth. Paper insulated cables have a specific inductive capacity of 3 and above, depending on the kind of insulating material. Rubber insulated cables have a specific inductive capacity of 5.5 and above, depending on the quality of rubber, etc. See article on "Power-Factor, Alternating-Current Inductive Capacity, Chemical and Other Tests of Rubber-Covered Wires of Different Manufacturers," in the Proc. of the A.I.E.E., June, 1907, Vol. XXVI., No. 6, p. 843.

H. W. F.

232—PHASE RELATIONS IN Z-CONNECTED TRANSFORMERS—In considering three-phase circuits is it not true that the instantaneous e.m.f.'s in two phases are in one direction while the e.m.f. in the third is in another? If so, would not the connections for Z-connected series transformers actually be as shown in Fig. 232 (a)? The signs refer to the instantaneous polarity of the transformers. In the JOURNAL for June, 1908, p. 407, under "Z-Connected Series Transformers," Mr. H. W. Brown assumes all three upper ends of transformers positive, and lower ends negative. Is this in keeping with the principles of three-phase transmission and his article on "Polarity of Transformers" in the May, 1908, issue, Vol. V., p. 261?

It was stated on page 261 of the JOURNAL for May, 1908, that if two conductors have series transformers
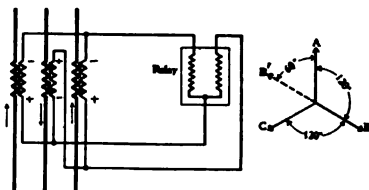
FIG. 232 (a)   FIG. 232 (b)

and the third line has none, the third may be considered the negative line; but if there are three transformers, and the phase difference between them is 120 degrees, it is not enough to say that one is positive and another negative at any instant. For a quantitative discussion of the various currents, their phase difference must be considered. The positive and negative signs then refer not to the entire system, but to the individ-

ual line. ' If the three phases, A, B, C, follow each other in the order named + B is 120 degrees after + A, and + C is 120 degrees after + B; whereas—B is 60 degrees before + A, and—C is 60 degrees before + B. —See vector diagram, Fig. 232 (b). There is, therefore, no disagreement between the more complete method of using the vector diagrams and the less complete but simple method of considering instantaneous directions of currents. **H. W. B.**

233—WATER RHEOSTAT FOR EMERGENCY STARTER—What are the connections for the arrangement of a water rheostat to be substituted for a controller for use with an induction motor as outlined in the "Experience on the Road" article on p. 53 of the JOURNAL for January, '09? If the grids of a 550-volt induction motor of the internal resistance, wound rotor type should burn out, is there any way of starting by means of a temporary device while waiting for new grids? **E. R. R.**

The connections are exactly the same as those of a three-pole water rheostat used as a loading device for a three-phase generator such as has been described in various articles in the JOURNAL.. It should be noted that the speed control of a wound secondary induction motor using external resistance for the speed adjustment requires slip rings, to which the external connections are ordinarily made; the controller regulates the amount of resistance and, thereby, the speed. It is evident that a three-phase rheostat such as described may be substituted for the control (or external) resistance. In the case of a wound rotor type of induction motor with internal resistance grids the application of a water rheostat for the purpose of control requires that a separate rheostat be provided for each line of the three-phase primary circuit. If the grids cannot be used, they may be removed from the rotor and the windings short-circuited so that the motor will operate as a simple squirrel-cage motor. The use of a water rheostat in the primary circuit, to give reduced voltage for starting, is explained in Question 220 in the JOURNAL for March, '09.

234—CONSTRUCTION AND THEORY OF ELECTROLYTIC LIGHTNING ARRESTER—What is the method of treatment in preparing the trays of the electrolytic lightning arrester? What is the strength of solution of the sodium phosphate electrolyte? What is the relation between the current which the arrester will discharge and the area of the trays? **E. S. H.**

The trays are treated by being subjected to current in a bath of. electrolyte until the e.m.f. between trays reaches about 400 volts. Sodium phosphate is not used. Borax and ammonium tartarate are common electrolytes. Borax is commonly used just under saturation. Special mixtures of other electrolytes are sometimes required. The equivalent spark gap is proportional to the total length of electrolyte and inversely proportional to the area of cross-section. For further information regarding equivalent spark gap refer to article on "Protection of Electric Circuits and Apparatus from Lightning and Similar Disturbances" in the JOURNAL for March, '08, p. 156, also No. 103 in the JOURNAL for July, '08. **R. P. J.**

235—SPEED CONTROL OF SHUNT WOUND ROTARY—Please explain why the speed of a shunt wound rotary converter can be controlled by variation of the resistance in the field rheostat when both the alternating-current and direct-current circuits are open. The machine is started by an induction motor on the end of the shaft and there is no electrical connection between the machine and the motor-starter. **B. L.**

This is readily explained when it is recalled that increase of field current results in strengthening the field which in turn increases the iron loss. The increase in load on the induction motor resulting from this gives an increase in the slip or, in other words, a reduction of speed. **F. D. N.**

236—LINE DROP COMPENSATOR—In a line drop compensator such as that referred to in the article on "Voltmeter Compensation for Drop in Alternating-Current Circuits," in the JOURNAL for January, '08, Vol. V., p. 26,

operated on a 2 200-volt light-
ing circuit, difficulty has been
experienced in obtaining cor-
rect indications on the volt-
meter with which it is used.
When the compensator was in-
stalled the current transformer
leads and the voltage leads
were connected to correspond
with the numbered contacts at-
tached thereto. There are ten
points on each side of the com-
pensator, five of which are for
the short contact strip and the
remaining five for the long
strip. An attempt has been
made to adjust the compensa-
tor by using the same number
of contacts on both the voltage
and current sides, as the resist-
ance and reactance factors of
the line are probably about
equal; but, no matter where
the contact strips are placed,
the reading of the voltmeter al-
ways indicates a higher voltage
at the end of the line than at
the power house. Would in-
terchanging the current and
voltage leads to the compensa-
tor remedy the trouble? w. H. H.

The compensator is evidently con-
nected in the voltmeter circuit in
such a way that it is *adding* to the
voltmeter reading an amount repre-.
senting the line drop instead of *sub-
tracting* it. The remedy is to reverse
either the current leads or the volt-
age leads. The station voltmeter and
the compensator voltmeter should
read the same when the contact arms
are on points *5* and *6* on both the
ohmic and inductive sides, for then
the windings of the compensator are
not connected in the circuit and
therefore have no effect. As the
arms are moved towards points *1* and
10, respectively, the reading of the
compensator voltmeter should be
lower. The ohmic side of the com-
pensator should be set to correspond
approximately to the calculated re-
sistance drop of the line and the in-
ductive side should then be set on the
points which will make the compen-
sator voltmeter agree with the one
at the end of the line. It would not
do to interchange the current and
voltage leads for this would throw

the voltage of the potential trans-
former on the series winding of the
compensator, which would be equiv-
alent to short-circuiting it.   w. N. D.

238—POLYPHASE WATTMETER CON-
N E C T I O N—P l e a s e a d v i s e
whether a polyphase wattmeter
connection for a three-phase,
four-wire circuit will give ac-
curate registration when the
neutral wire is not used. There
are no shunt transformers used
and the secondaries of the
series transformers are delta-
connected. The shunt taps for
the instrument are connected
to the neutral wire that is
brought out from the machine,
but there is no connection be-
tween the load and the neutral
line in the case under consider-
ation. Please give a diagram
showing the correct way to
connect a standard polyphase
w a t t m e t e r, a three-phase
power-factor meter and three
ammeters, including the three
series transformers, on such a
system.   w. J. S.

In connecting meters to a three-
phase—four-wire circuit, it makes no
difference whether or not the neutral
wire is used for the transmission of
power. It is simply necessary that
there be a connection to the gener-
ator in order to give the proper volt-
age relations in the potential circuits
of the wattmeter and power-factor
meter. The readings of the instru-
ment are accurate in either case. The
connections of a wattmeter, a power-
factor meter and three ammeters
may be made to three series trans-
formers on a four-wire circuit, but,
if power is to be bought or sold by
the integrating wattmeter, greater
accuracy may be obtained by putting
the wattmeter on one set of trans-
formers and the power-factor meter
and ammeters on a separate set. In
the article on "Meter and Relay Con-
nections" in the JOURNAL for Feb-
ruary, '09, a diagram (Fig. 1, p. 113),
suitable to the present case, is dis-
cussed. It shows an indicating watt-
meter instead of an integrating type,
but the connections are the same with
the two kinds of meters.   H. W. B.

A Method of Improving Power Plant Economy It is customary when purchasing alternating-current generators to stipulate that they shall carry their rated load at a power-factor of 80 percent or of 90 percent, but it frequently happens, in stations which supply a large number of induction motors, that the power-factor reaches so low a value that the generators are fully loaded while the steam plant is considerably underloaded. For example, assume the case of a station with two turbo-generator sets, the generators being rated for a load of 90 percent power-factor, while the load on the station has a power-factor of 75 percent. Then when a generator is carrying full-load, its turbine will be carrying only about 80 percent full-load. When the load exceeds the capacity of one generator, it is customary to start up the second set and divide the load between the two, in which case each turbine carries about one-half normal load, and therefore operates with poor economy. Instead of doing this, the second set may be started up and put in parallel with the first, then the steam cut off from the second set, which will continue to run, however, being driven by the first set. If, now, the field of the second machine is strengthened, it will take leading currents from the bus-bars, and by proper field adjustment it may be made to compensate for the whole of the wattless current, so that the load on the first set will have unity power-factor. Under this condition, the first generator will not be fully loaded till its turbine is overloaded ten percent. The majority of steam turbines are able, however, to carry very heavy overloads, and in general the higher the load the better the economy. Thus the use of the second machine as a synchronous motor will permit one turbine to be run at an overload of ten percent and with high economy, whereas with both sets operating as generators, the turbines will be working at about one-half load and with poor economy and the generators at a little more than one-half load.

If the generator is rated at 80 percent power-factor, the use of the second machine as a motor permits the turbines to be run with 25 percent overload before its generator is fully loaded.

It will be necessary to maintain a vacuum on the turbine, which is being motored in order to keep down the losses and heating in the turbine. A certain amount of power will be required for maintaining this vacuum, and there will be, also, friction and windage, iron and copper losses in the synchronous motor, but there would be practically the same losses in this machine and the same energy required for maintaining the vacuum when it is operating as a generator as when it is motoring.

It should be noted that the machine which is running as a motor may be turned into a generator at a moment's notice by opening the steam valve, as it is already in synchronism with the other machine.

Where there are several machines running in parallel supplying a load of low power-factor, one machine running as a motor may not have sufficient capacity to bring the power-factor of the load to unity on the other machines, but a very considerable improvement in power-factor can always be effected, usually enough to permit the shutting down of one of the turbo-generator sets, and hence the running of the others with better economy. It is possible, of course, where there is a large number of machines, to run more than one as a motor.

<div align="right">J. S. Peck</div>

Electric Steel Furnaces

The decision of the United States Steel Corporation, recently announced, to adopt the Heroult electric furnace for steel refining at two of its plants is of much importance. Heretofore the development of the electric furnace for steel making has not been undertaken by practical men in the large steel companies, but rather by electro-chemists, a number of whom have developed several practical types of furnaces and have carried their experiments so far as to erect independent electrical steel works. For two years or more engineers of the steel corporation have been making a close study of the subject, both abroad and in this country. Two Heroult furnaces have been in operation for some time at the McKeesport and at the Syracuse works, but the object of these is to make special steel electrically instead of by the crucible process. The furnaces now being

built are the largest ever constructed, having a capacity of fifteen tons each and estimated outputs of 300 tons or more per day of 24 hours.

At South Chicago, where power is available, both locally and from Gary, metal is to be taken from the Bessemer converter and passed through the electric furnace for further refining in the process of making extra high-grade steel rails. There has been a persistent demand for some time for better steel for rails than that produced by the Bessemer converter, and this process, which amounts to making rails of tool steel quality, may prove to be the salvation of the Bessemer converter.

At the Worcester works of the corporation another Heroult furnace of fifteen tons capacity is being installed. Here the molten metal is obtained from two 50 ton open-hearth furnaces and further refined in the electric furnace for use in making special steel wire. The results of the operation of these two plants will furnish an interesting comparison of the use of electric furnaces for improving the quality of steel from Bessemer converters and from open-hearth furnaces. In these operations the electric furnace does not enter as a direct competitor to established methods in steel making, but takes the molten metal from the converter or open-hearth furnace after the usual operations have been completed. Then, in the electric furnace, under the improved conditions as regards impurities, and the control and range of temperature, the refining process is carried on.

It is reported that there are now in operation or in course of erection twenty-four Heroult furnaces, eleven Stassano furnaces, eight Girod furnaces, ten Kjellin induction furnaces, ten Roechling-Robenhauser modified induction furnaces and some small Colby furnaces, all of which are abroad except the two Heroult furnaces above mentioned, and the Colby furnaces. While most of this development is in Europe, where steel refining seems to have gotten beyond the experimental stage, the fact that the United States Steel Corporation has adopted the electric furnace for large tonnage products, such as rails and wire, which in 1906 comprised one-third of the total steel output, gives assurance that there will be no more lagging behind. While no definite announcement has been made, it is reported that another Heroult furnace of the same size is to be installed at Homestead, and that if these furnaces prove satisfactory others of thirty ton capacity or larger will be constructed.

On account of the increased interest in the electric furnace due to its commercial application in the steel industry, the article in this

issue on "The Electric Furnace and Some of Its Applications," by Mr. William Hoopes, is especially appropriate at this time. His article gives in condensed form a comprehensive idea of the development of the different types of electric furnaces and of the various commercial products obtainable. In the latter part of his article he explains the difficulties encountered in the application of the electric furnace to the manufacture of high-grade steel and how they are being overcome. Mr. Hoopes is an expert on this subject and has kept in close touch with the progress of electro-metallurgical development for many years.

The A. I. E. E. Anniversary   The celebration of the twenty-fifth anniversary of the founding of the American Institute of Electrical Engineers by the dinner at the Hotel Astor on March eleventh was a notable occasion. No society representing any other branch of science or of engineering can present such an advance during its first quarter of a century. Prominent on the program and representing the charter members—of whom nearly twenty-five percent were present—was Professor Elihu Thomson, a pioneer in the electrical engineering work of this country and one of its recognized leaders. Following him was Mr. Frank J. Sprague, another electrical pioneer, whose notable work has made an indelible record on electric railway development, who represented the past-presidents of the Institute and presented to Mr. T. C. Martin, the oldest living past-president, a handsome silver cup from his fellow past-presidents in well-merited recognition of his continued and efficient interest and activity in Institute affairs, particularly in connection with the Engineering Societies' Building.

It is significant that those who were most active in the beginning of the industry which is now so great are still in the prime of life and are among its most active workers. The Institute has grown until the meetings of many of its sections exceed in attendance, and possibly in interest as well, those of the Institute itself for many of its early years. The Institute has been a most effective factor in advancing this electrical growth—a more important factor than many imagine. Its transactions, presenting a constantly growing panorama of the advance in electrical engineering, and its meetings and papers, exerting a unifying and co-operative force among engineers, have directly and indirectly done much to bring American electrical practice to its present high standard. It is sig-

nificant, for instance, that power transmission, a department which presents a most rapid and substantial growth during the past dozen years, is also the department in which operating and consulting engineers have joined most actively with those of manufacturing companies in the discussion of theory and practice. The notable freedom and frankness in the presentation of papers and in their discussion has brought about a general co-operation among engineers connected with the various phases of transmission work, which has contributed very largely to the rapid perfection and proper use of apparatus and methods that have established power transmission on its present basis.

The American Institute of Electrical Engineers may well congratulate itself upon the part which it has taken in the electrical achievements of the past twenty-five years and may look forward with inspiration and confidence to larger usefulness in the future with its increasing magnitude of electrical undertakings and the far-reaching responsibilities which will be placed upon the electrical engineering profession. CHAS. F. SCOTT

A Suggestion to Engineering Apprentices Shop training for electrical engineering graduates is a matter of the greatest importance to the graduates who are striving to become engineers, and also to those who require the services of men thoroughly trained in the design and construction of electrical apparatus. As most of us have our own ideas of what constitutes the best training, ít is often difficult for one to understand the other's point of view, and thus enable all to work together to secure the best results. When a young man completes his college course, his desire is to secure as quickly as possible a comprehensive knowledge of shop methods and at the same time to become familiar with the mechanical construction of all kinds of electrical apparatus. To accomplish this end the majority of the engineering students, who enter the regular courses provided for them by manufacturing concerns, wish to flit quickly from one department to another, spending only a very limited time in each. course. It is the aim of the writer to present to the young man who desires to become a practical and substantial engineer, the advantages of a thorough knowledge of one department or of one line of work over a more general knowledge covering a wider scope.

All of the larger manufacturers of electrical apparatus provide courses in their factories, for the training of technically educated

men.   The scope and methods adopted in these concerns vary.   The company with which the writer is connected offers to engineering graduates a course of broadest possible opportunity if proper advantage is taken of it.   However, those of us who come in every-day contact with the young men as they progress through the shop, and who have charge of the work on which they are employed, cannot help being impressed by the fact that the opportunities offered by the shop work are not fully appreciated.

In order to secure the hearty co-operation and assistance of the foreman for whom he is working in the shop, the apprentice must give the foreman good reasons for preferring his service to that of ambitious young men who can be hired at the gate and who, while having much less education and natural ability, are anxious to obtain steady positions and a permanent means of livelihood at smaller rates of wages than the apprentice demands.   Instead of going to work with this idea, however, the college man seems to feel that his reason for being in the shop is to learn generalities—that two weeks is a very long time in which to learn the things which interest him on any one class of work and that he must quickly move along in order not to waste valuable time.

The motto of the apprentice should be, "To learn a few things well and in all their detail."   There is probably no other business in which attention to details is of such vital importance as in electrical manufacturing.   A man's value is measured, not by the things of which he has a smattering knowledge, but by those things which he has mastered.   When a few things have been thoroughly mastered, other problems are more easily solved and a man's value is increased.   How many engineering apprentices are there who, after spending a year and a half or two years in a shop, can go into the engineering department and give good suggestions and advice as to the details of design which go to improve the apparatus and cheapen its manufacture?   Probably very few, and yet such advice is just what the designing engineer needs and is willing to pay for.

Under the departmental plan of manufacturing, the works and engineering departments are divided into separate departments, such as Railway, Power, Industrial, etc.   Each of these departments is practically complete within itself, and thus apprentices may enter one of these departments, and follow the various operations through the different sections as raw material is being converted into finished apparatus, and finally into the testing department where the apparatus is tested and where the greater amount of the time in the

shop will be spent. Then, when possible, the course should extend into the corresponding division of the engineering or drafting departments, where the experience gained in the shop can immediately be put to practical use.

The advantages of such a course as this, over one in which the student passes promiscuously from one department to another, are many. Chief among them is the increase in mutual interest and understanding between foreman and apprentice. A man cannot expect to be more than tolerated around the shop unless he makes himself of value to his employer by an amount at least equal to the compensation which he receives. One safe rule to follow in selecting a man for advancement is to select the man whom the foreman does not wish to lose. Such a man demands respect and is sure to receive it.

It may be said that a course such as outlined narrows a man and limits his opportunities in the general engineering field. As a rule this is not true, since the electrical engineering field is at the present time so broad that even the broadest of general engineers must specialize to a considerable extent, and before one can hope to be even a fair general engineer he must have been a good special engineer. In order that the apprentice may become familiar in a general way with the entire works, there should be opportunities for occasional visits to the various departments in the shop. Such visits cannot fail to be of much greater value to one who is perfectly familiar with all the methods and details in one section than to one who has generalized entirely.

It is believed that young engineers who have been through the shop in any kind of a course will concur with these opinions and it is hoped that they will exert their influence with incoming men to show them the wisdom of following such a plan.

C. W. JOHNSON

INCREASING THE EFFICIENCY OF FACTORY POWER HOUSES

R. A. SMART

THE economic design and operation of power houses—the steam generating machinery, the apparatus for converting the energy of steam into mechanical and electrical energy, the efficiency of all the various kinds of auxiliary apparatus in use, as well as power-house efficiency as a whole—all of these subjects have severally and collectively been discussed and re-discussed in the technical magazines and in book form. There is another phase of the subject, relating specifically to the factory power house, on which little data has been published. In this article are mentioned briefly a number of important points which the designer and the operator of factory power houses should keep prominently in mind.

In general, what is true of the power plant which is manufacturing current for sale is also true of the power plant which is merely an accessory to the factory which is in the business of manufacturing and selling other commodities. But from the very fact of its being an accessory to a manufacturing plant rather than the manufacturing plant itself, there are certain features pertaining to the factory power plant which are distinctively its own. These features are unfortunately of a character which tend to make it less economical than the commercial power house. The points here considered will relate chiefly to the steam apparatus. Chief among these features is the fact that in the majority of cases the factory power house furnishes a considerable part of its steam for other purposes than the generation of mechanical and electric power. As this steam is often used in small quantities and at widely separated points, it is impracticable to collect and return the water of condensation to the power house. On this account and until steam meters come into more general and practical use, it is very difficult to determine some features of the economy of the power plant. For example, in order to determine the combined economy of the auxiliary apparatus in the power house which supplies steam only for power generating apparatus and auxiliaries, it is necessary only to measure the amount of water supplied by the feed pump to the boilers; to measure, or estimate with reasonable accuracy, the loss from the boiler by leakage; and to measure or estimate from indicator cards or otherwise the steam consumption of the prime

movers, a quantity which can be found with a fair degree of accuracy. The remainder is the amount of steam used collectively by the auxiliary apparatus. If, however, an unknown portion of the steam generated is sent into the shop to be used in various ways and in various places and in such a manner that all of the returns cannot be collected and measured, an unknown element is introduced into the equation, which makes the solution little better than a rough approximation. So little is known of the steam consumption of small units that it is difficult to arrive at a direct determination of their steam consumption, thus making it necessary to resort to the method by differences just referred to. While this may seem a small point, yet it is almost impossible to obtain high efficiency without some knowledge of the amount of steam used and wasted by the
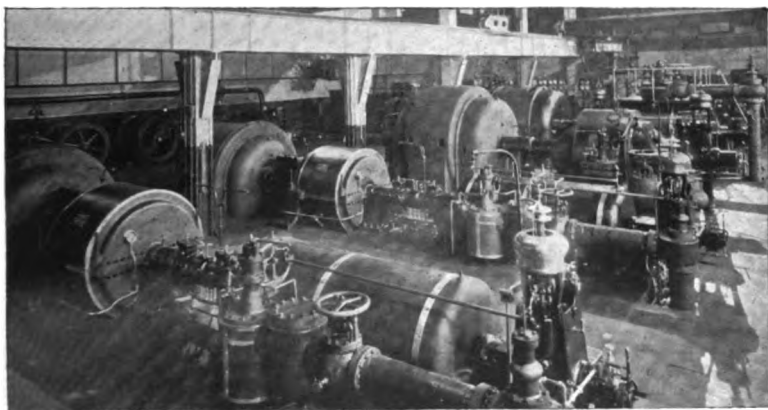
FIG. I—A FACTORY ENGINE ROOM EQUIPPED WITH STEAM TURBINES

auxiliary apparatus. It is difficult to impress on power house attendants the necessity for economy in this direction, or to eliminate the wasteful members of the auxiliary family and substitute for them more improved and economical units.

This same feature of the factory power plant, the miscellaneous small uses of steam, is also disastrous to economy in another and more serious way. The small miscellaneous demands for steam usually make necessary the use of some form of steam trap which is supposed to pass only the water condensation and prevent the escape of steam. It is unfortunately true that the majority of these appliances are traps in fact as well as in name for, while furnishing a sense of security against the needless waste of steam, they are permitting the escape of both steam and water in a manner which

it is difficult to detect. It is a curious commentary on the state of design of steam apparatus that a large number of so-called steam traps which are installed to prevent steam waste are designed on a plan which is calculated to result in rapid deterioration and increasing loss of efficiency. A trap which is intended to separate the water of condensation from high pressure lines should be so designed that the opening and closing of the valve is made quickly and positively and that by no chance can it remain in a slightly open position. The moment wire-drawing occurs, due to a partially open position, the valve begins to cut and thus its usefulness as a trap is gone. Illustrations of a number of trap valves and seats which were in service only a few weeks, showing the wearing away of the valves
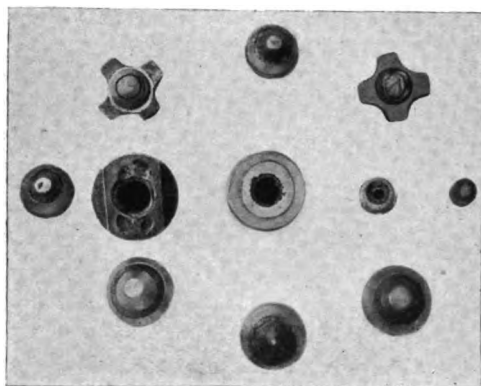
FIG. 2—TRAP VALVES AND SEATS
Showing erosion after a few weeks' service.

and seats, due to erosion, are given in Fig. 2.

Another feature of the shop power plant which is not conducive to efficiency is the fact that it is usually difficult to arrange the accounting in such a manner as to make it possible for the power house superintendent to know the cost of supplies and repairs. Often practically all electric auxiliaries belonging to a power house are, for convenience, wired from circuits supplying shop apparatus, thus making it difficult to estimate what portion of the electric output should be charged back against the power house and not counted in with the net current output. It is axiomatic that the first step in improving economy is a knowledge of losses, and if each item of power house accounting cannot be kept in such form as to present an itemized statement of charges and accounts, wastes and inefficiencies will remain undiscovered and unremedied. The factory power plant does not in most cases maintain a repair shop of its own, as its steam and perhaps electrical repairs are made by some of the manufacturing departments. This makes necessary some efficient method of cost segregation in order that labor and material charges

may be placed in the power house account. Further, the labor and material charges for upkeep of that portion of factory structures occupied by the power house should be charged to the same account.

The equipment of steam generating and steam using apparatus for the factory power house need not be greatly different from that employed by the commercial power house. The same features of steam generation and use which make for highest economy are equally applicable to both types of power plants.
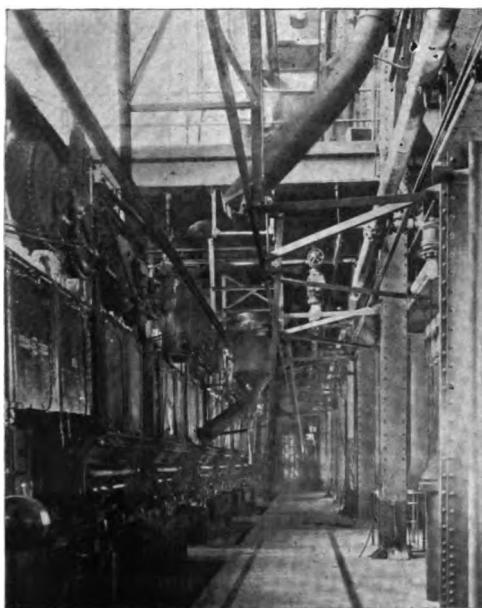
FIG. 3—A DOUBLE DECK FACTORY BOILER ROOM

The Boilers—No variation from what is commonly accepted as good boiler design need be made for the factory plant. The merits of different types of boilers, first cost, operating cost and convenience of repair are fairly well understood. The total c a p a c i t y should be large enough to meet all reasonable r e q u i r e ments. The amount of steam required for the power plant itself can be fairly well estimated, but c o n s i d e r a b l e care should be taken in determining the amount of steam required for heating purposes and for miscellaneous apparatus, ovens, etc. Liberal allowance must also be made for condensation in the long lines of steam pipes which are to be found in most manufacturing establishments, and for wastage from traps from which the condensation is not returned to the boilers. These quantities are usually difficult to estimate, the usual tendency being to under-estimate rather than to over-estimate them.

It is common practice, in deciding upon the number of boilers needed for given steam requirements, to accept the builders' rating, which is based upon an evaporation of about three pounds of water

per hour per square foot of heating surface. This is a conservative rating and is without doubt the proper one to use for general purposes.

However, the writer advocates the practice of running water tube boilers continuously at not less than 25 percent above rated load, provided the furnace is properly designed for this rate of combustion, (an important consideration), and that sufficient draft is obtainable to take care of the peak load. With furnaces of usual proportions it has often been shown that the efficiency decreases with an increased rate of combustion. While this is undoubtedly true with ordinary furnace construction, there is evidence, first, that the loss of efficiency is largely in the furnace and not in the boiler proper, and second, that with a design of furnace having adequate volume of combustion chamber and length of flame way, the total efficiency of the boiler need not be less at 125 percent of builders' rating than at rated load. The writer has conducted tests on 600 hp water tube boilers in which the equivalent evaporation at 25 percent overload was not less than at rated load.

Furthermore, with boilers of modern design provided with
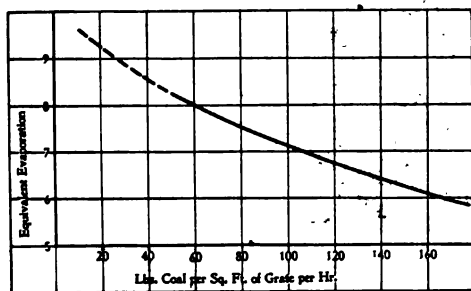
FIG. 4—CURVE SHOWING RELATIONSHIP BETWEEN
EVAPORATIVE EFFICIENCY AND RATE OF COMBUS-
TION FOR LOCOMOTIVE BOILER

furnaces having no departure from what may be called accepted practice, the decrease in evaporative efficiency with an increase of load from 100 to 125 percent of normal rating should not be more than two percent, and this loss at the coal pile will be more than offset by the fixed charges and operating costs involved in the alternatives of larger boilers or additional boilers of the same size which would be required to produce the excess power if operated at normal rating. These latter alternatives require the provision of additional floor space, piping and breeching, and giving opportunities for additional heat losses by leakage and radiation.

As showing the conservatism of stationary boiler design, an interesting comparison can be made with average locomotive boiler performance. Water tube stationary boilers operating with a draft

of from one-fourth to one-half inch, and burning from 20 to 30 pounds of coal per square foot of grate surface per hour, will show in every-day practice an equivalent evaporation of from seven to ten pounds of water per pound of coal of fair quality. In comparison with this may be quoted the extremely severe condition of locomotive boilers which are of the fire-tube, internally fired type, which are not commonly considered as efficient as the water tube type. These boilers operate on drafts of from two to six inches, and burn from 50 to as high as 150 pounds of coal per square foot of grate surface per hour. Under these conditions the boiler performance has been found by exhaustive tests made by Dr. W. F. M. Goss, at the Purdue University locomotive testing plant, using Indiana block coal, to follow very closely the laws given herewith.

$$D = 0.037 \ G \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$
$$E = \frac{10.08}{1+0.00421 \ G} \dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$
$$E = 10.08 - 0.296 \ H \dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Where D=Draft in inches of water
E=Equivalent evaporation
G=Pounds of coal per square foot of grate per hour.
H=Pounds of water per square foot of heating surface per hour

In Fig. 4 are shown results from the second formula. If the curve be extended to a lower combustion value (as shown by the dotted line) the evaporative efficiency for rates of combustion common to stationary practice is not less than that which is accounted good performance for stationary boilers in every-day operation.

Enlarging the Combustion Chamber—As commonly designed, the distance from the grate to the first row of tubes is not great enough to allow of anything approaching perfect combustion except at the very lowest combustion rates. With draft sufficient to operate the boiler at normal rating, the actual time consumed by the combustible gases while passing from the fuel bed to the nearest heating surface is but a small fraction of a second, and as the process of combustion is arrested by the lowering of the temperature of the gases upon contact with the heating surface, the length of flameway is usually too short to secure complete combustion. To remedy this difficulty, it is often possible to change the baffling of the boiler by removing the bridge wall further to the rear, lining the underside of the lower row of tubes with a baffle or arch of fire brick, and thus cause the flames to travel a longer distance before coming in contact with the heating surface. Fig. 5 illustrates a possible arrangement, the full lines showing the altered baffling and the dotted line the original baffling. The average length of flame is increased by this arrange-

ment from five feet six inches to eight feet three inches or 50 percent. If with this boiler a stack connection could be made from the top near the front of the boiler, a still better arrangement could be made by making a combustion chamber under the full length of the boiler and allowing the gases to move up through the rear, pass down through the middle and up through the front pass and thence to the stack, only slight alterations to the original baffling being necessary. Various schemes may be used to fit boilers of different descriptions and if the work is properly done it will be found to result in an increase in furnace and in total boiler efficiency.
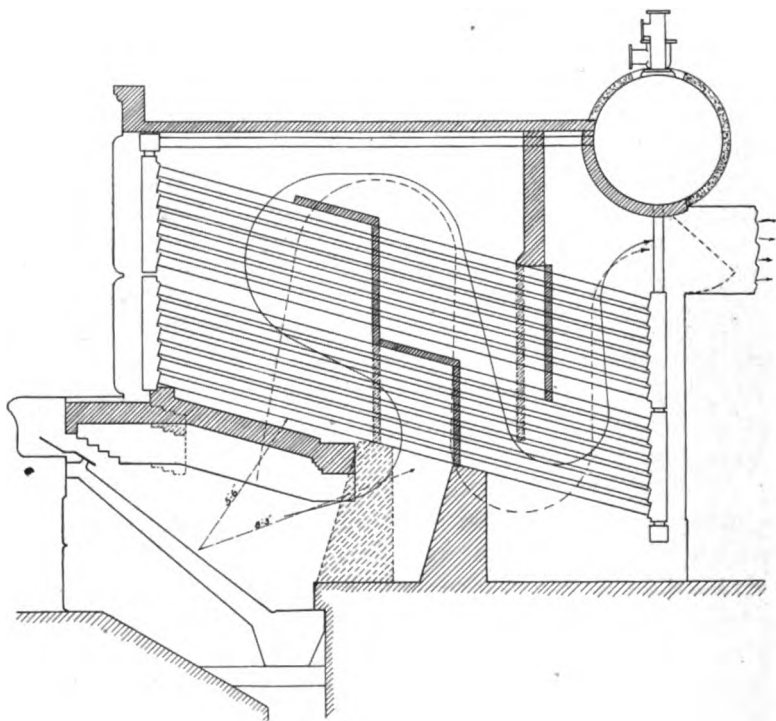
FIG. 5—A METHOD OF IMPROVING FURNACE EFFICIENCY BY RE-ARRANGEMENT OF BAFFLING

In reconstructing the baffling on existing boilers, care must be exercised to avoid decreasing the effectiveness of the tube heating surface. However, the superior efficiency of the heating surface should permit of some reduction in effective area in the interest of better combustion, with the net result of a higher total boiler efficiency.

Draft—The question of installing a mechanical draft plant in-

stead of a chimney should be viewed from two points, namely, first cost and cost of operation, and second, desirability from the standpoint of relative draft obtainable and ease of regulation. Considering the question in the light of increased boiler ratings, a mechanical draft plant for medium sized plants will be found to compare favorably in cost with a stack of the dimensions necessary to secure the required draft, and from an operating point of view will be found to be much more flexible than natural draft. The automatic regulator commonly used in connection with mechanical draft tends toward economy by automatic regulation of the speed of the fan and hence the draft, in accordance with the demands of the load.

In Fig. 6 is shown a typical diagram of the steam pressure in a plant of 9 000 nominal horse-power in which approximately 50 percent of the boilers are equipped with mechanical draft. Under such conditions the fan engine regulators are obliged to show unusual activity in order to maintain constant steam pressure for the entire group of boilers, including those which are furnished only with natural draft. Under such unusual conditions it is evident that the regulators were performing their function in a satisfactory manner. A part of this draft installation is shown in Fig. 7, the regulator being in the steam pipe at the right. ·
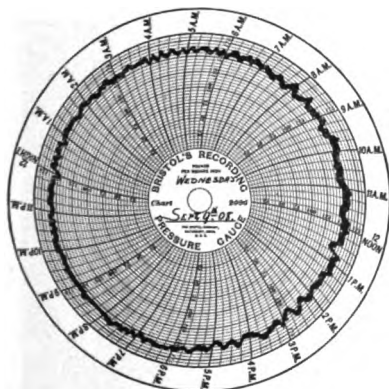
FIG. 6—TYPICAL STEAM PRESSURE DIA-
GRAM SHOWING EFFECT OF FAN EN-
GINE REGULATORS

Gas Analysis—One of the most effective means of keeping track of furnace conditions is by the analysis of waste gases. These analyses can be made to determine not only the efficiency of combustion and the sufficiency of the air supplied, but also whether the boiler setting is permitting air to leak into the furnace in sufficient quantities to seriously affect the boiler efficiency.

In making these analyses, too much weight should not be placed upon the percentage of CO_2. There are several appliances on the market which give continuous records of this quantity if they are intelligently operated. These instruments are good in themselves, but unless the analysis is carried further to include the percentage of CO and O, a full knowledge of the efficiency of combustion will not be obtained. Increasing percentages of CO_2 do not necessarily

mean increasing furnace efficiency, as it is quite possible that with higher values of CO_2, an increase of CO may take place. In other words, if reliance is placed alone on the percentage of CO_2, the fireman who succeeds in raising this percentage may actually be wasting coal in the process.

To serve as a general guide to those who have not followed this matter closely, it can be said that under reasonably good conditions the CO_2 should be between nine and ten percent, the O should not be greater than four or five percent, and the CO should not be over 0.3 per cent. A convenient means of taking samples of gases is by means of a continuous sampling vessel, which may be adjusted to take a sample over a period of six or twelve hours, or longer. In Fig. 8 is shown a home-made sampler of this description. In setting up the carboy and connections, the joints between pipes, tubing and stopper should be sealed to prevent leakage of air.
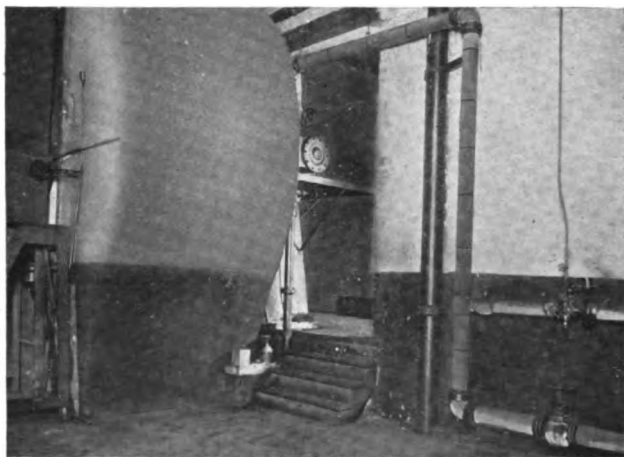
FIG. 7—INDUCED DRAFT FAN, ENGINE AND REGULATOR

As a result of analyses of the flue gases, two important points should be established. First, that the air supply is of the right volume and is introduced into the furnace at the right point. What this amount is or where it should be introduced cannot be broadly stated without a knowledge of the character of the boiler and the furnace, and the conditions of operation. While the proper thickness of fire to be carried with different coals and different grates is a matter of first importance, it can be said in a general way that too little attention is paid to the introduction of heated air over the fire. This is a matter concerning which there exists a good deal of difference of

opinion, but the writer believes that, if properly arranged and handled by an intelligent fireman, the introduction of heated air above the fire in proper amounts, depending up the draft, is a step in the direction of furnace economy, and a careful investigation of this matter by means of analyses of furnace gases, will in most cases result in better combustion and a decrease in the coal bill.

The second point, that of air leaks in the boiler setting, is one which needs constant watching. This is a disease to which all boiler settings are heir and one which is insidious in its progress. When it is realized that with a boiler setting which is tight in the ordinary acceptance of the term, an infiltration of air amounting to 20 percent in volume has been found to take place, one begins to realize the

FIG. 8—CONTINUOUS SAMPLING APPAR-
ATUS FOR FLUE GASES

serious effect of leaks due to cracks in the setting, around the cast iron frames of clean-out doors, etc. It has been found at the Government Testing Station in Pittsburg that the common practice of using double walls with an air space between may be a detriment, rather than an advantage. To make such a setting efficient as a heat insulator, the space should be subdivided by headers placed both horizontally and vertically and should be filled with some non-conducting material, such as asbestos. As ordinarily built with communicating air spaces, the arrangement is a positive detriment on account of the difficult of getting at the leaks in the inner wall of the setting.

An additional precaution which gives good results is to cover the entire setting on the outside with some semi-elastic compound which will block up the porous places in the brick work and which possesses sufficient elasticity to allow for the necessary expansion and contraction.

THE ENGINES

In the choice of prime movers, omitting from consideration those plants which can make use of water power and those where

natural or producer gas are available, the choice lies between com-
paratively slow speed reciprocating engines and steam turbines. One
feature of the engine installation should receive special attention in
the layout of a factory power house, namely, the provision for ob-
taining exhaust steam for heating purposes. The losses in distribu-
tion incident to high pressure steam heating are sufficient in the
majority of shops to make that method of heating impracticable.
Unless separate low pressure boilers are maintained for heating pur-
poses, or the heating requirements are so small that there is suffi-
cient exhaust steam from the auxiliaries to heat both the feed water
and the shop, provision must be made in the layout of the main
engine units for this purpose. If the engines are non-condensing the
problem is simple, but if they are condensing, provision should be
made for steam heating, either by installing a sufficient number of
non-condensing units which can be run during the winter time for
heating purposes and held as spares in the summer time, or, as has
been done in a few cases, provide a number of main units which
may be successfully run either condensing or non-condensing. It is
obvious that the question of economy while running non-condensing
in the winter time is not of great importance since without such ar-
rangements it becomes necessary to furnish live steam either directly
or through a reducing valve for heating purposes. It is considerably
cheaper to run non-condensing engines for heating purposes, even
at efficiencies considerably below those of similar condensing en-
gines, than heating by live steam.

<div align="center">RECORDS</div>

Coal—The largest item of expense connected with power house
operation is that of coal and it is therefore important that accurate
records of the amount of coal burned be kept. The simplest method
is to weigh the coal as delivered to the power house, either in cars
or wagons, and at the end of stated periods, either weekly or
monthly, to estimate the amount of coal remaining in the hoppers and
bins, the difference being the amount consumed during the period.
Another method involves the use of automatic weighing hoppers con-
nected with the coal elevators which weigh the coal as delivered to
bins and hoppers. This record, in connection with a periodic estimate
of stock, will give the monthly consumption. A third method makes
use of weighing hoppers in the distributing system, which takes the
weight of the coal as delivered to the stokers or on the floor for hand
firing. This latter method is non-automatic and introduces large

opportunity for error on the part of the fireman. It has been the writer's experience that this error is so large that the coal record obtained is unreliable.

Water—The water record should be taken at at least two points: First, in the main supply pipe to the power house, to give the total amount of water used and furnish a basis for charging the power house account; and second, in the feed line, to give the amount of water fed to the boilers in order to determine their evaporative efficiency. These two amounts differ considerably; first, because a considerable portion of the water used by the power house is consumed in other processes than boiler feeding, and second, because there is usually a considerable amount of returns from heaters and other apparatus which is delivered to the boilers and re-evaporated into steam.
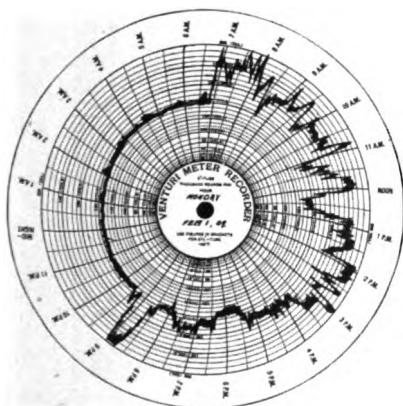
FIG. 9—VENTURI METER CHART

The first record is easily taken by the use of reliable makes of cold water meters, but the second record, involving the measurement of hot water, is not easily obtained with accuracy. Ordinary cold water meters are unsatisfactory when used to measure hot water, and recourse must be had to some simpler mechanism, such, for instance, as the Venturi meter. If the flow of water is comparatively steady and is not affected by the pulsations due to the pump stroke, this form of meter gives good satisfaction, especially when used in connection with recording devices. (See Fig. 9.)

Oil and Waste—The record of the amount of oil and waste used per unit of time presents no unusual difficulties. The amounts of different kinds of oil used should be kept separate and a standard allowance determined in the form of cents per engine hour, which may serve as a guide in determining the efficiency of lubrication. For example, the following allowance have been found to be satisfactory in introducing the allowance system:

ENGINE OIL	CYLINDER OIL
2.5c per main engine hour.	10c per main engine hour.
0.5c per exciter engine hour.	2c per exciter hour.
0.1c per auxiliary hour (including pumps, stoker engines, etc.)	0.1c per auxiliary hour.

With care in the use of lubricant it should be possible to make slight reductions in the above allowances after the system has been in force for some time.

Labor—The labor expenditure should first be divided into two items, operating labor and maintenance labor, the latter including all labor expended in upkeep and repairs. The operating labor should again be subdivided into boiler room labor and engine room labor, and further into the various classes, such as firemen, coal handlers, ash handlers, engineers, oilers, etc. In factory power houses the operating labor is easily obtainable, but to obtain the maintenance labor it is necessary that the cost and time keeping system employed be such as to throw the expense of all power house work into one
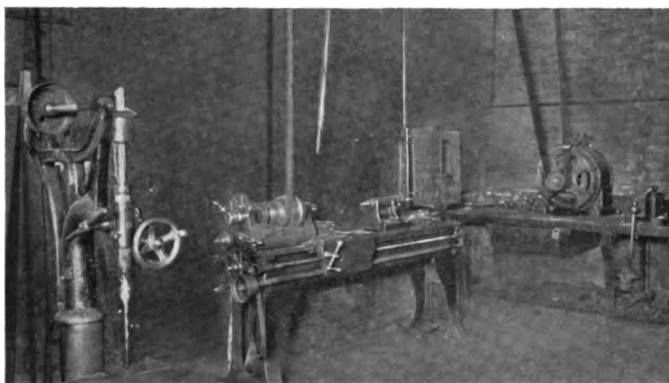
FIG. 10—A CORNER IN A SMALL REPAIR SHOP IN A FACTORY
POWER HOUSE

or more power house accounts. If this is successfully done there should be no difficulty in determining the entire charge against the power house operation and maintenance.

If conditions are such that a small repair shop can be arranged for the use of the power house, many repairs which otherwise must be made by some of the manufacturing departments of the factory and charged to the power house account, can be made with the regular power house force without additional cost. A small equipment of this kind, similar to that shown in Fig. 10, will often be found to be a very profitable investment. The necessary machines can often be obtained from machines discarded from the regular factory equipment.

The repair accounts may be conveniently divided into repairs to building, repairs to steam equipment and repairs to electrical equip-

ment. Under such a division, the labor and material involved in the upkeep of that portion of the plant from the coal bunker to the coupling between the engine and the generator, is chargeable to repairs to steam equipment. All labor and material required for the upkeep of the plant from the generator to the switchboard is chargeable to repairs to electrical equipment. If carried to a logical conclusion, such a division as indicated above would mean that the repairs to the motors of motor-driven pumps and any other electrical apparatus included in the steam auxiliaries should be charged to repairs to steam equipment. Also under this ruling, repairs to the engine of a steam-driven exciter would be charged to the electrical equipment. Practice and opinion on this point differ. It is the

writer's opinion that the weight of argument is in favor. of charging the upkeep of such units by the method suggested above. A convenient further sub-division divides the repairs to steam equipment between the apparatus located in the boiler room and that located in the engine room.
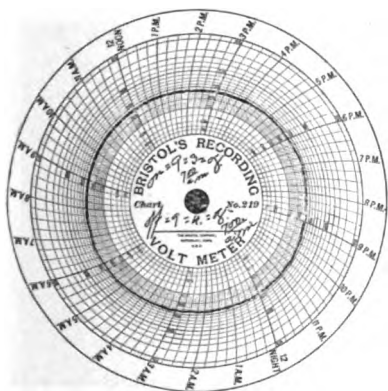
Logs — The forms upon which daily and monthly records are kept necessarily vary widely, depending upon the equipment

FIG. II—A GRAPHIC VOLTAGE RECORD

and conditions surrounding each plant. The records should be sufficiently in detail to give all the necessary data required for making up the power house accounts and keeping track of the details of operation. Daily graphic records of such items as steam pressure kilowatt hours, voltage, frequency, etc., are of great assistance in keeping track of the details of plant operation.

A graphic voltage record is shown in Fig. 11 and a graphic frequency meter and record in Fig. 12.

POWER HOUSE ACCOUNTING

The system devised for keeping account of the factory power house costs should seek to arrive at two main figures; the cost of steam as supplied to the shop for heaters, ovens and similar apparatus, and to the engine room for use in main generating units and auxiliaries; and second, the cost of net current supplied to the shop, this being the total current generated, less the amount used

within the power house. The cost of current should include the value of the steam consumed by the engine room and auxiliaries, at the unit price previously determined under the head of "Cost of Steam." As a basis for making up the power house account, the following items should be obtainable from the records kept:

ITEM	LABOR	MATERIAL
Engine room wages	A	
Boiler room wages	B	
Superintendence	C	
Repairs steam equipment (engine room)	D	H
Repairs steam equipment (boiler room)	E	I
Repairs electrical equipment	F	J
Repairs buildings and miscellaneous	G	K
Coal		L
Water		M
Oil, waste and supplies		N

In addition the following data should be on record:

1—Pounds coal burned.
2—Pounds water evaporated.
3—Total kilowatt hours generated.
4—Pounds steam per kilowatt hour, main engines.
5—Pounds steam required for boiler room auxiliaries.
6—Kilowatt hours required for boiler room auxiliaries.
7—Pounds steam required for engine room auxiliaries.
8—Kilowatt hours required for engine room auxiliaries.

Items 5 and 7 are usually difficult to obtain and must be estimated from the best information at hand. To the sum of the amounts obtained for the auxiliary units, should be added an amount sufficient to cover leakage, radiation and other losses. Items 6 and 8 can readily be obtained by voltmeter and ammeter readings from each electrical unit. Having obtained these values with a fair degree of accuracy for a period of months, the next step is to determine the average percentage of items 5 and 7 to the total steam evaporated, and the percentage of items 6 and 8 to the total kilowatt hours generated, these percentages to be used in subsequent calculations and to be represented as follows:

W=percent of steam required for boiler room auxiliaries to total water evaporated in pounds.

X=percent of steam required for engine room auxiliaries to total water evaporated in pounds.

Y=percent of gross kilowatt-hours required for boiler room auxiliaries.

Z=percent of gross kilowatt-hours required for engine room auxiliaries.

These percentages will naturally vary somewhat from month to month, but in the main they will average about the same.

With the above information a monthly statement of power house accounts can be made. For the sake of illustration, figures are given below for a month's operation of a factory power house for the month of December, during which time a large part of the steam generated was used for heating and miscellaneous purposes other than current generation. These figures cover operating and mainte-
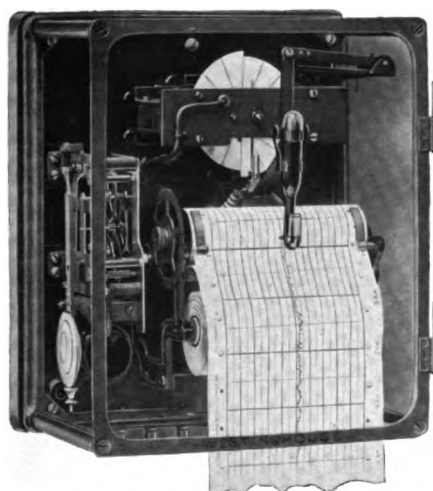
FIG. 12—GRAPHIC FREQUENCY METER AND RECORD

nance expense only and do not take into consideration interest, depreciation, taxes, etc.

MONTH	DECEMBER
1—Pounds coal burned..	18,114,000
2—Pounds water evaporated (for all purposes).................	124,400,000
3—Total kilowatt hours—gross.................................	1,533,000
9—Pounds steam required for boiler room auxiliaries (item 2 × item W)...	6,349,000
10—Pounds steam required for engine room auxiliaries (item 2 × item X.).	4,238,000
11—Kilowatt-hours required for boiler room auxiliaries (item 3 × item Y)...	38,370
12—Kilowatt-hours required for engine room auxiliaries (item 3 × item Z.)	114,930
Pounds water evaporated per pound of coal—actual...........	6.870

COST OF STEAM

Coal (item *L*) (reduced to $1.00 per ton)..........................$ 9,057.35
Water (item *M*)..　635.82
Boiler room labor (item *B*)...................................　1,683.48
Superintendence (item *C*) × 50 percent........................　195.85
Oil, waste, etc. (item *N*) × 10 percent...........................　20.46
Repairs to steam equipment—boiler room (items *E* + *I*)..........　1,027.80
Repairs to building (items *G* + *K*) × 50 percent....."..............　14.72

　　　Total $12,635.48

Total per 1 000 pounds evaporated—gross [÷item *2* × 1 000]......$ 0.1015
Total per 1 000 pounds evaporated—net [÷(item *2*—item *9*)1 000].　0.111

COST OF CURRENT

Steam for main engines (item *3* × item *4* × 11.1c).................$4,065.00
Steam for auxiliaries (item *10* × 11.1c)...........................　470.00
Engine room labor (item *A*)....................................　814.69
Superintendence (item *C*) × 50 percent........................　195.85
Oil, waste, etc. item *N*) × 90 percent..............................　184.18
Repairs to steam equipment—engine room (item *D* plus *H*)........　448.20
Repairs to electrical equipment (item *F* plus *J*)....................　579.60
Repairs to buildings (item *G* plus *K*) × 50 percent.................　14.72

　　　Total $6,772.24

Total per kilowatt-hour—gross (÷ item *3*)...........................0.441
Total per kilowatt-hour—net (total cost ÷ by item *3*—items *11* and *12*)..0.491

The above analysis of expense is subject to some criticism because no charge has been rendered against the cost of steam on account of the electrical auxiliaries in the boiler room (item *11*). However, this is usually a small item and to include such a charge increases the complication of the accounting and no serious error is introduced by omitting it. Proper account is taken of the item when figuring the cost of current per net kilowatt.

The analysis given above is a general one and does not give in segregated form such items as follows:

    Cost of coal handling per boiler horse-power per month.
    Cost of ash handling per boiler horse-power per month.
    Cost of water treating per 1 000 gallons.

These figures are easily obtained by a proper distribution of the boiler room labor charge. For the plant above referred to these figures are as follows:

Cost of coal handling per boiler horse-power per month.................5.5c
Cost of ash handling per boiler horse-power per month (vacuum sys-
    tem see Fig. 13)..4.5c
Cost of water treating per 1 000 gallons...............................0.6c

POWER COSTS

The cost of power as reported in various localities and in various kinds of plants, differs very materially. This is due to variations in the cost of coal, water, etc., and also very considerably to the difference in the methods of cost keeping. The principal item of difference is that due to the cost and heating value of coal, which is the largest single item in the power house account.
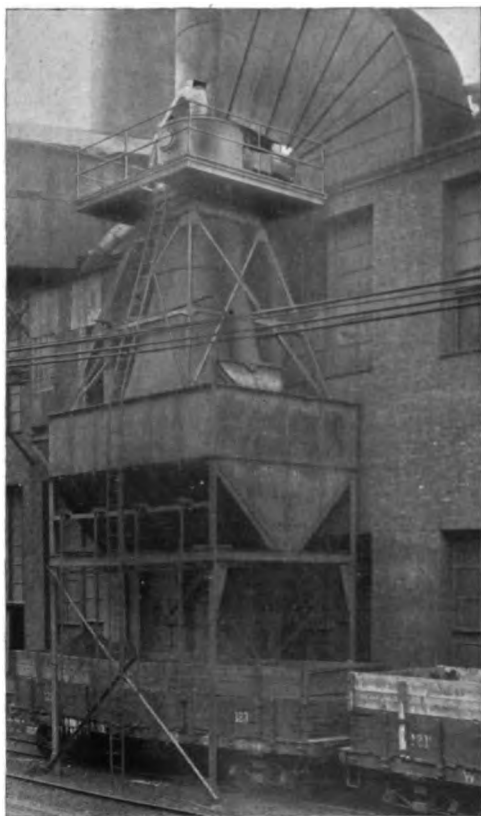
In Table I are shown power costs per month taken from a variety of plants and showing the costs of power in plants of different kinds and sizes. These costs have been reduced to a common basis of $1.00 per ton for coal. While there are a number of facts necessary to place the costs given on a s t r i c t l y comparative basis, as, for instance, the heating value of the coal, the unit value of labor, the relative load factor, etc., it is believed that the cost of power in average manu f a c t u r i n g plants should fall within the range of costs given in this table for similar sized plants. As stated at the outset, there are many wastes, principally of steam, which occur in a large manufacturing plant and which operate in a measure to reduce the efficiency of the steam generating portion of the plant, but since it is not uncommon that 50 percent of the steam is used for other than current generating purposes, the cost of steam delivered to the engine room is usually somewhat less than it would

FIG. 13—VACUUM ASH HANDLING SYSTEM
View of separator and hopper

TABLE I.—POWER COSTS IN CENTS PER KILOWATT-HOUR

PLANT	CAPACITY Boiler Hp	CAPACITY Kw	OUTPUT Kilowatt-hours per month	ITEMIZED EXPENSE Actual cost of coal per ton	Coal at $1.00	Wages Inc. Supt.	Oil, waste & supplies	Water	REPAIRS St.Equip.	REPAIRS El.Equip.	REPAIRS Plant	Total Expense Cost of current per Kw-Hr.
1. British Municipal Plants—average, 1907				3.00	0.133	0.260	0.040			0.200		0.673
2. New England Municipal Plants—aver. 1908		4 700	533 000	4.50	0.160	0.358	0.040	0.030	0.065	0.033	0.025	0.710
3. Boston Edison (aggregate of several plants), 1908		55 000 total	7 380 000	4.00	0.116	0.192	0.031	0.024	0.042	0.056	0.015	0.476
4. Boston Elev. (average of all plants), 1906		38 500		3.18	0.148	0.170	0.060	0.040	Included in supplies			0.448
5. A St. Railway Plant				1.55	0.440	0.199	0.024		0.083	0.019	0.005	0.810
6. A St. Railway Plant				2.66	0.302	0.133	0.025		0.035	0.025	0.003	0.539
7. A Light & Power Plant				2.98	0.320	0.287	0.048			0.004		0.660
8. A Ry. & Power Plant				3.62	0.276	0.217	0.023	0.022	0.035	0.010	0.015	0.598
9. A Commercial Power Plant	3 000		450 000	4.79	0.145	0.360	0.025	0.034	0.12			0.680
10. An Ideal Plant		1 200		3.00	0.245	0.280	0.053	0.020	0.038	0.0038	0.0038	0.640
11. An Ideal Plant	2 000	1 500	375 000	2.00	0.200	0.100	0.020					0.592
12. An Ideal Turbine Plant		1 500		2.00								0.484
13. A Manufacturing Power Plant	9 200	9 250	1 250 000	1.00	0.235	0.160	0.013	0.020	0.051	0.020	0.001	0.500

NOTE.—Operation and maintenance costs only, based on net kw. at the switchboard.

References: 1—Annual Supplement of Statistics, *Electrical Times* (London), 1907. 2 and 3—*Eng. Mag.*, Feb. '09. 4—'Steam Power Plant Engineering," Gebhardt. 5, 6, 7 and 8—*St. Ry. Rev.*, Oct. 20, '02. 9—*El. Rev.* Jan. 23, '09. 10—*El. Rev.*, July 4, '08. 12—*Power*, Jan. '07.

be in a commercial plant of equivalent size, due to the larger amount manufactured, and hence the cost of current should be no greater than in the commercial plant of equivalent size.

One of the largest items in maintaining an efficient power house is an intelligent and active personnel. No amount of money spent in efficient apparatus and labor and material saving appliances can off-set the extravagance of an ignorant and careless working force. An efficient working force is the greatest money-saver obtainable. To obtain such a force requires constant attention on the part of those in charge, by instructions as to the most efficient methods of operation, by providing apparatus for recording the p o w e r house performance, and by the publication of results obtained.

FIG. 14—CHART SHOWING POWER HOUSE PERFORM-ANCE
Kept in power house for the information of attendants

Graphic records are of use in maintaining even steam pressures, constant voltage, etc. It is also of great service to keep in the power house a chart (Fig. 14) which may be added to from 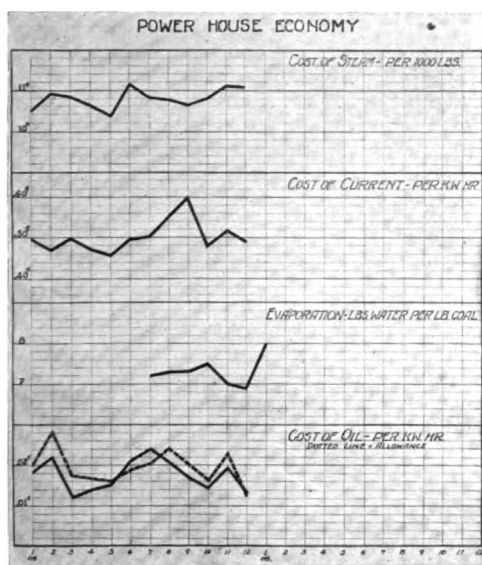month to month, showing such items as pounds of water per pound of coal, cost of steam per 1 000 pounds, cost of current per kilowatt-hour, etc. The publication of such records creates an interest in the boiler and engine room forces which stimulates them to put forth their best endeavor to cheapen the output.

The general appearance of the plant has an important effect on the economy of operation. A judicious amount of money spent on paint and polish, window cleaning and the like, brings good returns. No man can do his best work or is stimulated to put forth the utmost endeavor amid dirty and slovenly surroundings. The character of the surroundings is usually reflected in the character of the

work which is performed in their midst. Emphasis should be put on keeping the power house clean and in order. It is customary to find the engine and generator room in good condition with clean floors, polished brass work, well lagged piping, etc., but the reverse is the rule in boiler rooms. It seems to be the assumption that they must of necessity be dirty and unkempt in appearance. For this reason special emphasis should be placed on a well-kept boiler room, especially as more money can be lost and gained in this end of the plant than in the engine end.

Every well regulated power house should possess a suitable gauge testing outfit. Gauge needles are usually fastened rather
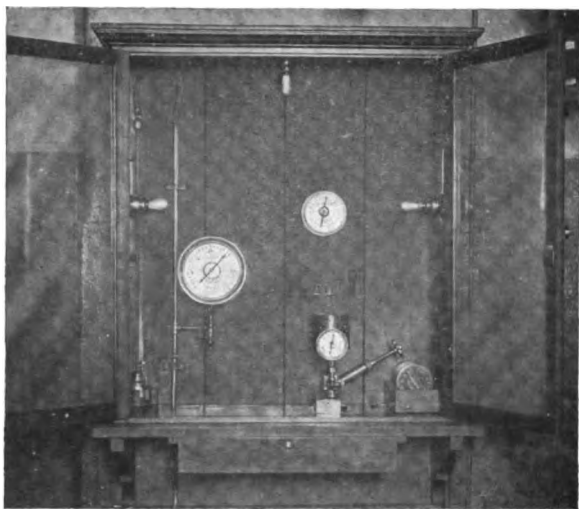

FIG. 15—APPARATUS FOR TESTING PRESSURE AND VACUUM
GAUGES

insecurely to their spindles and there is a likelihood of their going wrong at any time. A slight water hammer in a pipe will often jar the needles loose or cause the point of the needle to shift. A master gauge with a simple device for comparing its rating with that of the gauge to be tested, is the least expensive apparatus obtainable. A better equipment is shown in Fig. 15. This consists of a dead weight gauge tester with the necessary wrenches, needle jack, etc., for pressure gauges, and a home-made vacuum tester shown at the left of the case consisting of a mercury tube with a connection at the bottom running to the air pump. A suitably graduated scale, adjustable for varying heights of mercury level in the cup at the bottom of the tube, furnishes a ready means of reading the vacuum obtained.

THE ELECTRIC FURNACE AND SOME OF ITS APPLICATIONS

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THE electric furnace is one in which the heat is furnished by the passage of current through some form of resistance and in which the sole object in the use of the electrical energy is to produce the necessary heat. This definition should be remembered as it is quite usual to find that, in the popular mind, the electric furnace includes electrolytic cells, such as those in which aluminum, calcium, magnesium and sodium are made, and in which the chief office of the electrical energy is to effect an electrolytic separation, the heating of the bath being merely incidental and continuous current being necessary for their operation. The electric furnace is operated by either direct or alternating current, as may be most convenient and suitable, and any reaction taking place within the furnace is pure heat reaction.

We have, therefore, to consider the electrical energy solely from the standpoint of its properties as a source of heat. One kilowatt, operating continuously for one year, develops the same amount of heat as does the burning of 2 140 pounds of 14 000 B. t. u. coal. If coal is valued at $1.50 per ton and is so burned that the combustion is complete and all of the heat usefully applied, it determines the value of one kilowatt year to be $1.60. It is, however, impossible in practice to obtain perfect combustion of fuel without the use of an excess of air, and it is impossible to usefully apply all of the heat of combustion except in heating a body which is continuously maintained at the temperature of the atmosphere, since for heating a body to a higher temperature the waste products of combustion must carry off some heat. The maximum temperature obtained, in practice, from the combustion of coal or of gases made from coal, is approximately 2 000 degrees C. The products of combustion of coal will, therefore, impart no heat to a body which is at a temperature of 2 000 degrees C and will impart all of their available heat to a body which is at atmospheric temperature.

The efficiency of the application of the heat of combustion will be dependent upon the temperature of the escaping gases and will be, for an atmospheric temperature of 0 degrees C, approximately

equal to the difference between 2 000 and the temperature of the escaping gases divided by 2 000. This does, not, however, take into account regenerative heating whereby the efficiency of fuel heating is materially increased. Fig. 1 shows the comparative values of one kilowatt year as compared with 14 000 B. t. u. coal at $1.50 per ton with varying temperatures of escaping gases. It may be seen from this curve that for the purpose of generating steam, where the gases would escape at about 300 degrees C., a kilowatt year would be worth only $1.90; for melting cast iron, where the gases escape at about 1 400 degrees, a kilowatt year is worth $5.35; for operating an open hearth steel furnace, with gases escaping at 1 700 degrees, the kilowatt year is worth $10.50.
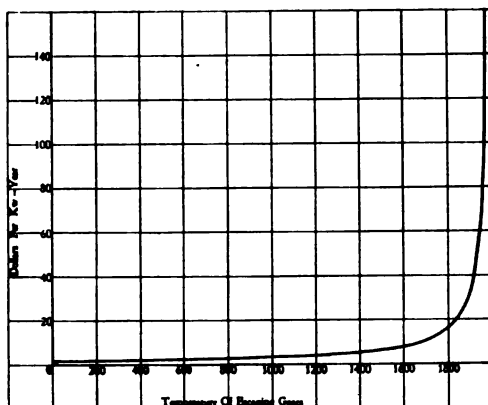

FIG. 1—CURVE SHOWING RELATION BETWEEN TEMPERATURE C. OF ESCAPING CASES AND SUBSTITUTION VALUE OF ELECTRICAL ENERGY FOR SUPPLYING THE SAME HEAT

In brief, inspection of the curve and knowledge of the fact that electrical energy is not obtainable anywhere in this country for less than $10.00 per kilowatt year, shows at once that, considered on the basis of its cost as a source of heat where fuel can be used, if the result to be accomplished permits the discharge of the gases at a temperature of less than 1 700 degrees C, electrical energy cannot compete with coal at $1.50 per ton, but that above 1 700 degrees C, its value increases rapidly, and at about 1 950 degrees C., coal ceases to compete with it. The availability of the electric furnace is, however, not determined by the cost of the energy alone, as it possesses individual characteristics, which are of importance and may justify a greater cost for the energy than expenditure for fuel would require.

An electric furnace consists essentially of:

1—A space enclosed by walls of refractory materials, preferably of high heat insulating qualities.

2—A resisting medium of suitable kind, in which heat is developed by forcing current through it.

There are three general types:

1—The resistance furnace, in which the heat is generated in a solid or liquid resisting medium, which may or may not be the furnace charge itself.

2—The arc furnace, in which the heat is generated in an arc between two electrodes above the charge, upon which it is radiated directly, as well as reflected upon it by the top lining of the furnace, · or the heat is generated by an arc between one or more electrodes and the furnace charge.

3—The induction furnace, in which the charge consists of conducting material which forms a closed circuit around a laminated iron core, the heat being generated within the charge by currents induced in it by a primary coil also surrounding the core. These three fundamental types are combined with each other to produce others, as shown later.

The advantages of the electric furnace are:

1—The heat is generated, either in the charge or in immediate proximity thereto, within the furnace walls with no exhaust gases, unless the process carried on produces them. Consequently the efficiency of application of the heat is very high.

2—Any desired temperature is obtainable, without diminution of the efficiency.

3—As a consequence of the second advantage, it is possible to carry on processes involving heat reactions which do not occur at all at temperatures obtainable by the combustion of fuel. This has resulted in making available several products which, prior to the advent of the electric furnace, were unknown or were merely chemical curiosities.

4—It is possible to carry on a process in any desired atmosphere and the product is not therefore contaminated with deleterious substances coming from the fuel gases.

5—It is possible to recover all volatile products, undiluted by air or gases of combustion, and this makes possible the saving of valuable by-products which are wasted when the process is carried on with fuel heat, on account of the difficulty of collecting these volatile products when diffused among large volumes of the products of combustion of fuel.

6—Absolute and accurate control of temperatures is readily obtained to an extent impossible in any other form of furnace.

APPLICATIONS

Aluminum Bronze, Ferro-Aluminum, Silicon-Copper.—The first applications of the electric furnace on a commercial scale were made by Cowles Brothers in Cleveland about 1884 and afterwards at Lockport, N. Y. This process consisted in the manufacture of aluminum bronze and ferro-aluminum from alumina and metallic copper or metallic iron. It was and is carried on in a resistance furnace, the charge for aluminum bronze consisting of a mixture of finely divided copper, alumina and carbon. The reaction which takes place is $Al_2O_3 + 3C = 2Al + 3CO$. The aluminum, as fast as formed, is taken up by the molten copper, forming aluminum bronze, which sinks to the bottom of the furnace and is tapped therefrom. The carbon monoxide gas passes off into the atmosphere. This reaction is one which begins and takes place slowly at about 1 900 degrees C. and is actually carried on at a temperature approximating
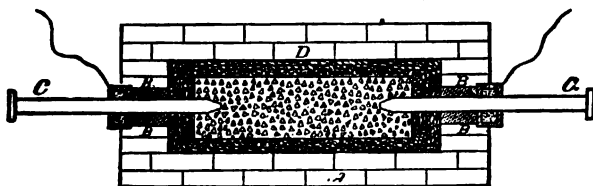

FIG. 2—PLAN CROSS-SECTION OF SMALL COWLES RESISTANCE FURNACE FOR MAKING ALUMINUM*

2 500 degrees C. It is strongly endothermic in ordinary fuel heated furnaces and is impossible of accomplishment therein, but proceeds regularly and economically in the electric furnace. It is impossible, however, to make pure aluminum by this method, since at the temperature necessary aluminum is volatile and is reoxidized or forms aluminum carbide as it passes out of the reducing zone.

A sectional view of one of the small early Cowles furnaces is shown in Fig. 2, and its construction is apparent without much explanation. It was about one foot square and five feet long. It was made of brick with a lining of charcoal previously washed with lime which serves as a heat insulating material. The charge filled the furnace from end to end and made contact with the electrode at each end.

In addition to being the first commercial electric furnace process, the Cowles installation at Lockport was notable for having

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*From "Aluminum," by Jos. W. Richards; Henry Carey Baird & Co., Philadelphia.

what was at that time by far the largest generator which had ever been built, it having a capacity of 300 kilowatts and being considered a wonder on that account.

Although aluminum bronze combines many of the most desirable properties of any metal, it has not come into extensive use by reason of the difficulty of working it, and ferro-aluminum, which was for a time used in the deoxidization of steel, has been superceded by pure aluminum. Consequently the Cowles plant is now principally engaged in the manufacture of silicon-copper, the reaction used being very similar to that used in the manufacture of aluminum bronze, except that silica is substituted for the alumina.

In this, as in all large furnaces, large currents and low voltages are used and extremely heavy bus-bars are necessary. Currents as high as 40 000 amperes at 30 volts have been used, and nearly all resistance and arc furnace work is carried on at less than 75 volts. The use of these enormous currents requires a bus-bar section so great as to make the bus-bars a very material portion of the expense of the furnace and render it desirable to locate the transformers as close to the furnaces as possible and to interlace the bus-bars in order to form the shortest possible loop and thereby avoid a low power-factor.

SECTION AND PLAN OF TILTING INDUCTION FURNACE

Current for electric furnaces now comes almost invariably from transformers and, as the resistance of the charge varies rapidly with the temperature, some means of regulation is necessary. This is usually accomplished either by means of an induction regulator or by varying the transformer ratio by means of a dial switch or contactors.

Carborundum.—The next important industrial application was the manufacture of carborundum. This is also carried on in a resistance furnace, the charge consisting of carbon, silica and salt, being laid up around a carbon core which extends from end to end of the furnace. Carborundum is silicide of carbon, and the salt takes no part in the chemical reaction carried on which is $SiO_2 + 3C = SiC + 2CO$. The temperature of formation of carborundum is about 1 830 degrees and at about 2 200 degrees it decomposes to graphite and silicon.

The principal use of the crystalline portion of the charge is as an abrasive. The amorphous portion was for a time used for the purpose of introducing silicon into steel, but has since been supplanted by ferro-silicon and is now used for refractory furnace linings, for moulding sand and for a variety of other purposes.
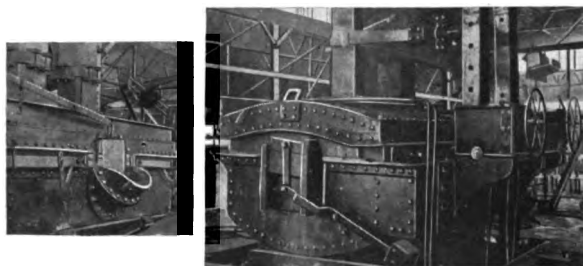
VIEWS OF HEROULT SERIES ARC TILTING FURNACE
Showing electrodes and method of pouring.

The discovery of the process for manufacturing carborundum was made by Mr. E. G. Acheson* and is said to have been accidental, the research being carried on at the time the process was discovered having for its object the manufacture of artificial diamonds.

Graphite—A companion industry, which has also been successful and is operated on a large scale, is the manufacture of artificial graphite, which is also due to Mr. Acheson. This process is also carried on in a resistance furnace and consists in electrically heating carbon to a temperature at which amorphous carbon is converted to graphite, which occurs at about 2 500 degrees. The desired form of the article is first obtained by moulding a mixture of amorphous carbon with a binder. When graphitized, the article retains the form in which it was moulded.

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*See article entitled, "Discovery and Invention," by Mr. E. G. Acheson in the Journal for October, 1906.

One of the advantages of the resistance type of furnace is that it may be built of almost any desired size and therefore operated in large units, with comparatively small heat losses and small costs for attendance. The resistance furnace is, however, not well adapted for handling materials of very low specific resistance on a commercial scale, on account of the very high current and low voltage involved.

*Calcium Carbide.*—The manufacture of calcium carbide, which is now one of the most solidly established and extensive processes carried on by the use of the electric furnace, was begun about the same time as that of carborundum. It is made from coke and burnt lime, generally in an arc furnace. The type of furnace in which its manufacture was carried on has undergone several changes. At that time a small portable furnace was used and the carbide was not tapped from the furnace. At present it is almost entirely manufactured in stationary furnaces and the product is tapped from the furnace. At the temperature of formation, calcium carbide

STEEL MIXER CONSISTING OF SERIES ARC, THREE-PHASE HEROULT FURNACE

is liquid. As the actual formation of carbide occurs in the neighborhood of 3 000 degrees C., all the ordinary refractory linings are unsuitable for its manufacture, and a frozen layer of the carbide itself is used for the furnace lining, the exterior of the furnace being air-cooled, although in Europe there are some water-jacketed furnaces used. The reaction involved in the process is $CaO+3C==CaC_2+CO$. In the most successfully operated plants, one kilowatt-year makes about two tons of carbide.

The principal use of calcium carbide at present is for the manufacture of acetylene gas, which is used for lighting and is beginning to be extensively used for heating purposes on account of the very high temperature obtainable when burning it with oxygen. What promises, however, to be the principal use of calcium carbide is its use in making calcium cyanamide. This is usually obtained in the form of a black powder having a chemical composition of $CaCN_2$. It is made by the action of atmospheric nitrogen, from which the oxygen has first been separated, on highly heated calcium carbide. This process is the most efficient method of fixing atmos-
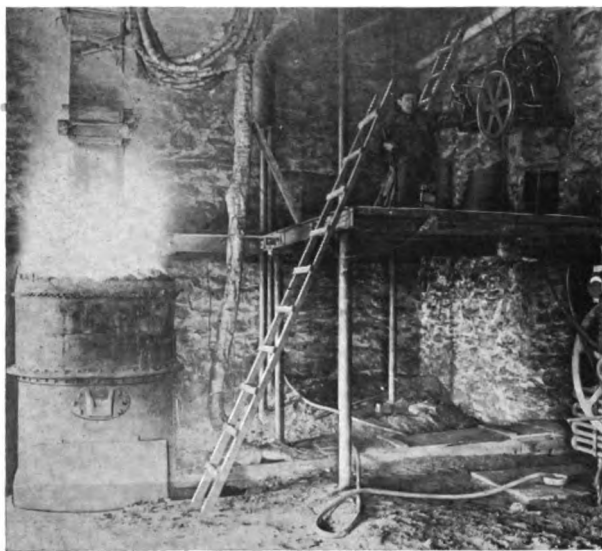
HEROULT ELECTRIC FURNACE FOR REDUCTION OF IRON ORE

pheric nitrogen which has so far been discovered. The fixation of one ton of nitrogen by cyanamide requires about two kilowatt-years. By direct combination of nitrogen and oxygen the best results so far produced have been about 6.4 kilowatt-years.

Several extensive cyanamide plants are under construction or in contemplation in this country and it is expected that eventually this material will take the place of natural nitre, as that grows more expensive through diminishing supply. Cyanamide may be used directly as a fertilizer without further treatment or as a source of manufacture of other nitrogen compounds. Ammonia is formed

from it simply by decomposition with superheated steam, and cyanides are formed directly by fusion with sodium chlorides or carbonates.

Ferro-silicon is manufactured in a furnace very similar to the carbide furnace, the charge consisting of iron or iron oxide, silica, and carbon. Under the heat of the arc, the reaction, in the case of the use of metallic iron, is $SiO_2 + 2C = Si + 2CO$, the reduced silicon being immediately taken up by the iron present and forming ferro-silicon. The manufacture of ferro-silicon in the electric furnace has grown to such an extent as to almost wholly supplant the ferro-silicon obtained from blast furnaces run for the purpose of its manufacture, and the price for the contained silicon has been very greatly reduced. The alloy most usually made is one containing approximately 50 percent of silicon, and has recently sold as low as $65.00 a ton, making the value of the silicon about $120.00 per ton. Its market price when made by the old method in blast furnaces was approximately $150.00 per ton.

Manufacture of High Grade Steel.—The most active and promising of the applications of the electric furnace is for the manufacture of high grade steels. This is a branch of the electric furnace industry of peculiar interest to Pittsburg as it promises to completely revolutionize the manufacture of crucible steel and to furnish a demand for many thousands of kilowatts of electrical apparatus of which it is hoped a goodly portion will be made and used here.

There are at present in use or being built plants for the electric refining or manufacture of steel having a combined capacity of 150 000 tons per annum. This does not sound very formidable when compared with the total of steel figures, but when it is considered that this business has been built up by men not previously engaged in the steel business and in the face of the skepticism of the steel manufacturers and that all of the product is either of a grade superior or equal to the best crucible steel and iron the figures do not appear insignificant. Nearly all of this development is abroad, but it is only a question of a short time when we shall take our rightful position, as we have already done in the other departments of the steel industry.
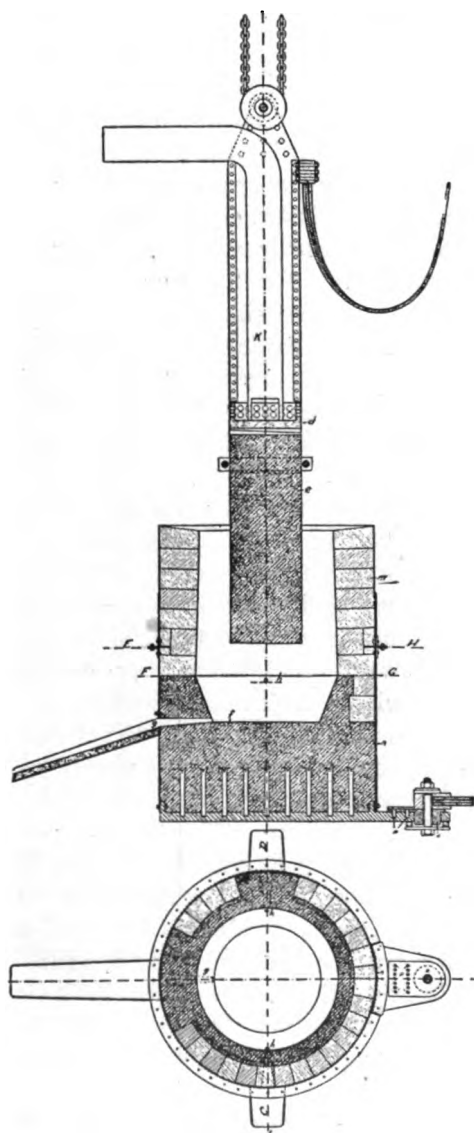
There is much discussion regarding the electrical production of both pig iron and steel directly from the ore, but as, at present, the proved production is only about three tons of pig and somewhat less of steel per kilowatt year, with a heavy expense for electrodes and high labor costs and fixed charges, the economy of the electrical

method does not appear, other than in exceptional locations where power is very cheap and fuel very expensive. Hence the subject is not of much local interest. What is of local interest, however, is the use of the electric furnace as an adjunct of the existing open hearth and Bessemer plants.

It has been proven, in European practice, that steel poured from either of these types of furnace can be refined, with the expenditure of not more than 300 kilowatt-hours per ton and a total expense of less than \$5.00 per ton, to a point where phosphorus and sulphur are both below 0.01 percent. Moreover, practically any desired alloy with tungsten, nickel, etc., may be made and any desired content of carbon, silicon and manganese achieved.

The refining process is carried on in either an arc or an induction furnace, the one in most extensive use being the Heroult furnace, which is a combination of the series arc and resistance furnace. There are two or more electrodes w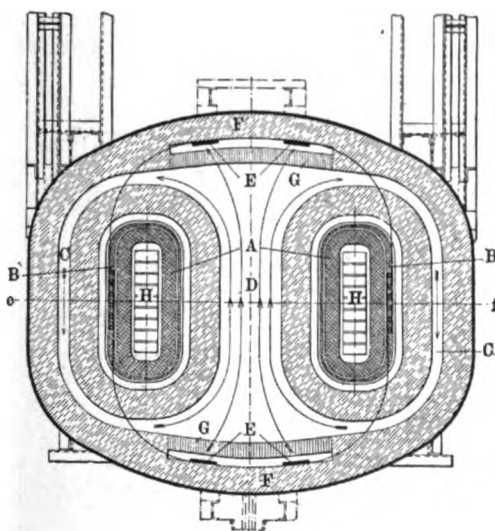hich are slightly raised above the slag resting on the steel bath. An arc is maintained between each electrode and the slag, the resistance feature being in the passage of the current

SECTIONAL VIEWS OF HEROULT ARC FURNACE FOR IRON ORE REDUCTION

through the slag which is a conductor at the temperature of operation. The electrodes are of different potentials and the arcs are in series, thus avoiding the necessity of making contact with the steel bath. This furnace is operated either single or three-phase and may be constructed in almost any size, an advantage it possesses over the induction furnace which has certain features rendering it difficult to construct in large units and yet retain a good power-factor.

The reason for the adaptability of the electric furnace to steel refining is that it can efficiently maintain the steel bath at a temperature so high that the desired reactions between the slag and the steel bath occur quickly and that a pure neutral or reducing atmosphere is maintained with no additions of sulphur from fuel gases. If, as appears from the results of European practice, open hearth steel can be converted to the best crucible steel for less than $5.00 per ton, there seems to be no question about the future of this branch of the industry.

PLAN SECTION OF ROECHLING-RODENHAUSER COMBINED INDUCTION AND RESISTANCE FURNACE

The two deleterious substances to be removed from steel, phosphorus and sulphur, are not readily removed by any reaction which operates completely for both. Both reactions involve the combination of the sulphur and phosphorus with lime, but for the complete removal, the phosphorus must be removed as calcium phosphate while the sulphur must be removed as calcium sulphide. Oxidizing conditions must obtain for the complete removal of phosphorus, which is oxidized to phosphoric acid which combines with the lime in the slag to form calcium phosphate.

At the same time as the phosphorus is removed in this manner, the sulphur is also oxidized to sulphurous or sulphuric acid, which combines with the lime to form calcium sulphate. Unfortunately, however, calcium sulphate reacts with the steel in the bath

re-forming iron or manganese sulphide. Therefore, for the complete removal of sulphur it is necessary to operate under conditions which will form calcium *sulphide* instead of calcium *sulphate*. In other words, the conditions in the furnace for the complete removal of phosphorus must be oxidizing and for the complete removal of sulphur must be reducing.

If the entire process of refining is carried on in an electric furnace, it is necessary to use two slags, one for the removal of phosphorus and the other for sulphur, the removal of the phosphorus being effected first and the slag poured off or its chemical character completely altered, a new slag being formed for the removal of sulphur. As this means practically two complete operations in the
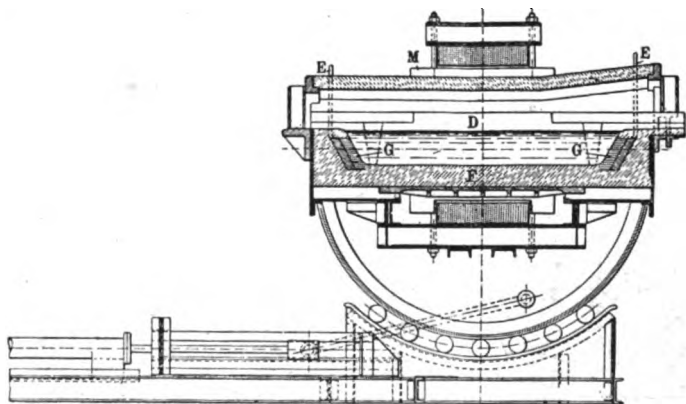
VERTICAL SECTION OF ROECHLING-RODENHAUSER FURNACE

electric furnace, many attempts have been made to remove both phosphorus and sulphur with a single slag, and some processes are so operated. As might be expected, however, when attempting to accomplish two objects with such diametrically opposed features, the resulting product is not of as good quality as when the removals are made separately. The practice where a single operation is used is to select material in which either the sulphur or phosphorus is already low and then to remove the other. When the electric furnace is used as an adjunct to an open hearth or Bessemer furnace this difficulty disappears because it is then customary to reduce the phosphorus to the desired point in the open hearth furnaces. The steel coming from the open hearth furnaces with the phosphorus removed is in a highly oxidized condition, but this does not matter as, after pouring into the electric furnace, it is de-oxidized by the

addition of carbon or carbides or of ferro-silicon. In an arc furnace there is some calcium carbide formed in immediate contact with the arc, and this effects a portion of the de-oxidization and de-sulphurization. With the combination of the open hearth furnace and the electric furnace, both the sulphur and phosphorus are removed very cheaply, although they may have been originally present in large quantities, and it therefore becomes possible to use materials containing much higher percentages of these two impurities and thereby to render available ores which have heretofore not been looked upon with favor. This feature seems likely to have an important influence on the steel business in the future, as high grade
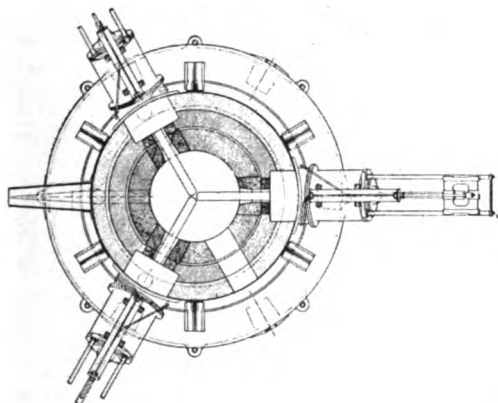
PLAN SECTION OF STASSANO ROTARY THREE-PHASE
FURNACE
For iron ore reduction and steel refining.

ores become exhausted and it becomes necessary to use the lower grade ores.

It appears probable that the electric furnace will eventually prove to be especially adaptable to glass making. Glass is a double silicate of calcium and sodium and is made by fusing together sand, limestone, and sodium carbonate or sodium sulphate. In the reaction which takes place the silica displaces the carbonic and sulphuric acids of the lime and soda. The carbonic and sulphuric acid portions of the mixture are volatile and pass off with the heating gases. For purposes of glass making, the lime contained in gypsum is just as good as the lime contained in limestone, and the soda contained in sodium sulphate is just as good as the soda contained in sodium carbonate. Theoretically, it should be possible to make a glass mixture of gypsum, sodium sulphate and silica; to do the heating in the electric furnace, and to collect as a by-product, for each

ton of glass, about three-fourths of a ton of sulphuric acid, which would be worth about as much as the glass. Inasmuch as there would be nothing passing off from an electric glass furnace excepting almost pure sulphuric acid, its collection would be very inexpensive, whereas it is impracticable in a fuel-heated glass furnace on account of the dilution with the products of combustion.

It should require not more than 400 kilowatt-hours per ton of
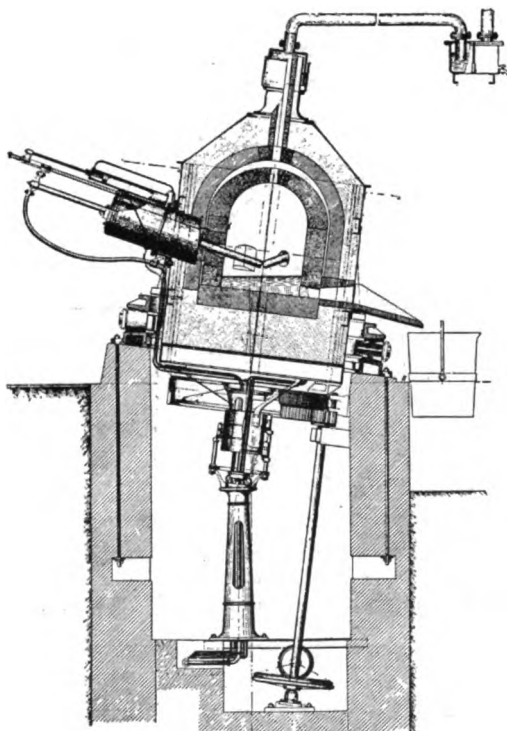
VERTICAL SECTION OF STASSANO FURNACE

glass, and for such a purpose it should be possible to generate this power in the Pittsburgh district for a sufficiently low rate so that the extra cost of energy in using an electric furnace would be only a small portion of the value of the by-product obtainable by its use.

[Note: The illustrations used in this article were furnished by *Electrochemical and Metallurgical Industry* through the kindness of Dr. E. F. Roeber, Editor.]

APPLICATION OF AUTOMATIC CONTROLLERS TO DIRECT-CURRENT MOTORS—III

CONTROL OF MACHINE TOOL MOTORS

D. E. CARPENTER

THE constant tendency in the industrial world is to increase the number of mechanical operations which can be performed by automatic means, allowing the attendants to give close attention to larger and more complicated problems. Hand tools and processes have given way to power-driven tools. No matter how perfect the tool, however, its usefulness depends on the ease and rapidity with which it can be controlled. Unquestionably the tool that will perform with the greatest accuracy and with the least attention from the operator, the work for which it was designed is the most desirable. This will leave the maximum portion of the operator's time and attention for those refinements which cannot well be delegated to machinery.

The substitution of electric motors for other forms of machine tool drive requiring frequent changes of gears and frequent belt shifting was a long step in advance. Not only are motors capable of giving greater refinement in speed adjustment than was possible with cone pulleys and gears, but the speed changes can be made in a small fraction of the time required by the older method. Direct-current shunt wound adjustable speed motors are admirably adapted for this service. The speed can be quickly adjusted by means of simple controllers, and at any adjustment will remain practically constant at all loads.

The greatest refinement in the control of machine tool motors is obtained by means of automatic controllers consisting of a master controller and several electro-magnetically operated switches in connection with suitable resistances for starting and speed adjustment. The magnet switches serve to start the motor, to cut out the starting resistance in steps at a predetermined rate, and in some special cases to reverse the motor. The master controller serves to start the operation of the magnet switches, to adjust the shunt field control resistance, and to open the circuit carrying the operating current to the magnet switches, thus causing them to open and stop the motor.

The master controller can be left set for any speed and the motor stopped by opening the line switch or a pilot switch as ex-

plained later; when the switch is again closed the motor speed will be automatically accelerated to that for which the controller is set. This feature is of great service in many machine tool operations, since the machine can be stopped to make some necessary adjustments of the
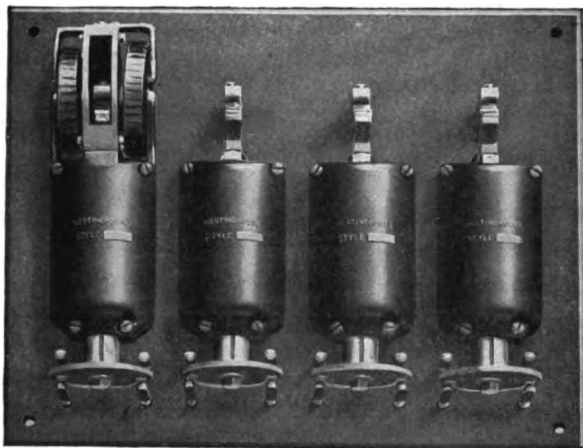
FIG. I—AUTOMATIC MAGNET SWITCH MACHINE TOOL CON-
TROLLER

tool or work, and again brought up to the exact speed at which it was formerly operating, all with a minimum of attention from the operator.

The rate of acceleration can be made to depend on voltage drop in the starting resistance or on the operation of a series accelerating relay. Acceleration by voltage drop is usually satisfactory for this class of service, but where very close results are desired and where the voltage is unsteady, a series relay may be preferable.

The master controller show in Fig. 2 is of the drum type and carries a special contact finger which slides over the contacts on a stationary face plate. The controller is entirely enclosed in an iron case and is provided with a suitable handle with a notching device.

The drum contacts are copper straps, or segments, so mounted as to slide under the stationary fingers and make contact with them when the drum is rotated. The drum also carries the movable finger for the face plate contacts.

FIG. 2 — MASTER
CONTROLLER

The notching device catches and holds the handles in each operating position until released by pressing the thumb piece. The only current passing through the master controller is the motor shunt field current and the current operating the magnet switches; hence, no blowout coils are required.

Provision is made in this master controller for obtaining six reverse speeds by reversing the shunt field current. A resistance is supplied for the field discharge. A mechanical latch stops and holds the master controller handle in the off position until released by means of the thumb piece, thus preventing inadvertent reversals when trying to stop. A positive stop can be arranged in the off
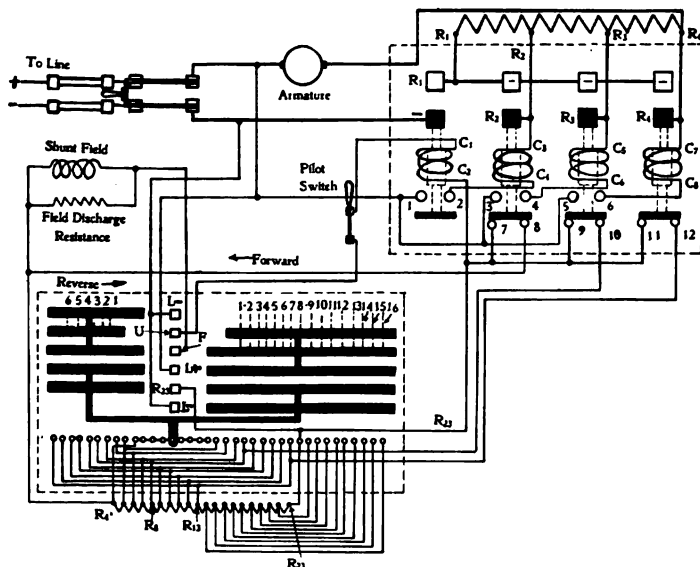
FIG. 3—DIAGRAM OF CONNECTIONS OF A FOUR-POINT AUTOMATIC MAG-
NET SWITCH MACHINE TOOL CONTROLLER

position to make the controller non-reversing. The magnet switches can also be arranged to reverse the armature current for full reverse service.

Fig. 3 shows the connections of a four-point, automatic magnet switch machine tool controller with a master controller arranged for 16 forward and six reverse speeds. The master controller drum is represented as developed, or laid out flat. The moving contact segments are represented by blackened bands, and their interconnections by heavy black lines; the finger for adjusting the field regulating resistance is represented by a blackened projection, the end of which

extends over a resistance contact terminal. The motor shunt field, the line circuit, and the magnet switches are connected with the stationary controller contact fingers L, U, F, etc., as indicated. The connections of the magnet switches are represented as from the rear of the panel. These switches act consecutively, beginning at the left, and may be referred to by number in the order of their automatic operation.

When the master controller is turned for forward direction of rotation the ends of the contact segments first slide under fingers F, $L+$, R_{23} and one of the fingers marked L—, thus connecting finger $L+$ with F, and R_{23} with L—. The shunt field is thereby subjected to full line voltage. Further movement of the drum causes finger U to make contact with a segment, and the first magnet switch then closes the motor armature circuit through all the starting resistance. The first magnet switch in closing also bridges an interlocking contact 1-2, thus closing the circuit through the operating coil of the second magnet switch. The second, third and fourth magnet switches follow automatically, the operation of each being delayed by voltage drop in the starting resistance. Continued movement of the controller handle cuts sections of the adjusting resistance in series with the shunt field, thus increasing the motor speed to the desired point. A few field resistance contact points in addition to those required for the 16 increased speeds are provided for making special adjustments that are sometimes necessary.

The connections are such that the motor always starts with full field strength regardless of the position of the master controller handle, and the field strength after all the magnet switches have closed depends on the setting of the handle. For example, assume that the master controller is set for maximum speed when the line switch is closed. The magnet switches immediately begin to close automatically in the order just indicated. The field regulating resistance is short-circuited through interlocking contacts 7-8 on the second magnet switch so that the shunt field is directly across the circuit until the second switch closes. Until the third magnet switch closes, its interlocking contacts 9-10 short-circuit all the field resistance except the portion R_4—R_8; accordingly, the closing of the second magnet switch not only short-circuits section R_1—R_2 of the starting resistance, but also cuts section R_4—R_8 of the field control resistance into circuit. Likewise, the closing of the third switch short-circuits section R_2—R_3 of the starting resistance and simultaneously cuts section R_8—R_{13} of the field control resistance into circuit, the re-

mainder being short-circuited by contacts *11-12* of the fourth switch. The closing of the fourth switch short-circuits the remaining section R_3—R_4 of the starting resistance and removes the short-circuit from the remainder of the field control resistance. The field resistance is not inserted when starting unless the controller is set for increased speed.

This arrangement has several advantages, some of which are as follows:

1.—No injury can result from too rapid operation of the controller, for the magnet switches will not operate faster than the rate for which they are set. The motor speed is thus brought gradually up to that corresponding to the position of the controller handle.

2.—Knowing from experience the proper position of the controller handle for a given piece of work, the operator can immediately move the handle to that point and then give his whole attention to the work while the motor is coming up to the required speed.

FIG. 4—DIAGRAM OF CONNECTIONS OF AN AUTOMATIC SWITCH CONTROL-LER FOR A PLANER WITH ONE MOTOR

3.—If adjustments of the work or tool are required, the motor can be stopped by opening the line switch or a pilot switch, with the assurance that when the switch is closed the controller will automatically bring the motor back to the same speed as before, provided the position of the master controller handle is not changed.

4.—By installing single-pole, single-throw pilot switches in the control circuit, one of which is indicated in the diagram, and locating these switches at various convenient points, the machine can be stopped by opening any one of these switches. On again closing the switch the motor starts and attains its original speed, provided other conditions in the circuits have not been changed.

Fig. 4 shows an arrangement of magnet switches and a field rheostat for controlling the main motor of a planer. Closing the line switch starts the motor with all starting resistance in series and also closes the circuit through the coil of magnet switch *I*. The acceleration is by the voltage control method. When the line switch is closed the shunt field receives full line voltage regardless of the adjustment of the field rheostat; the field current passes through inter-

locking contacts *2-1* to the negative circuit at *a*. The closing of switch *I* short-circuits a section of starting resistance and may cut in a portion of the field resistance, depending on the position of the rheostat handle; but this portion can never be greater than from the off position to point *b*, since this point is in connection with the negative line at *a* through interlocking contacts *6-5*. The closing of magnet switch *II* short-circuits the remaining section of starting resistance and may cut in the remainder of the shunt field resistance, provided the rheostat handle is turned to the extreme right. On closing the line switch the controller will therefore start the motor
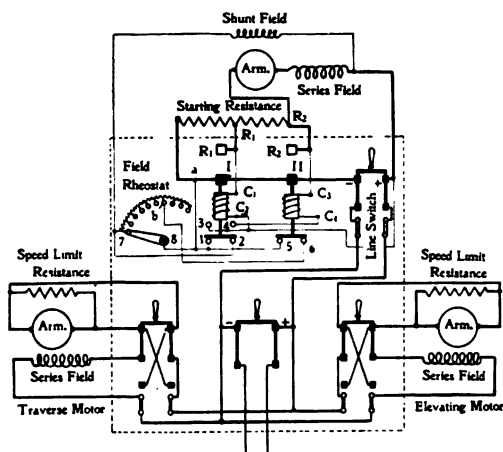
FIG. 5—DIAGRAM OF CONNECTIONS OF AN AUTO-
MATIC SWITCH CONTROLLER FOR PLANER WITH
THREE MOTORS

and automatically accelerate it to the speed for which the shunt field rheostat is adjusted.

Fig. 5 shows the foregoing arrangement of magnet switches and a shunt field rheostat for controlling the main motor of a large planer, and also shows double-pole, double-throw reversing switches arranged for controlling the elevating motor and the traverse motor for the crossheads. Resistances are shown connected in shunt with the armature of each of the latter motors, for limiting the speed. Figs. 4 and 5 are suggestive also of the many other combinations for automatically controlling the operation of machine tools.

DYNAMIC BRAKING

HENRY D. JAMES

I N a previous article* under the subject of "Friction Brakes," the various forms of mechanical brakes operated by magnets were described. Dynamic braking is obtained by connecting a motor so that it operates as a generator delivering energy to an external circuit. This circuit may be a local circuit through suitable resistance or it may be the power supply circuit.

APPLICATION

Dynamic braking is used on various classes of apparatus, such as elevators, skip hoists, trolley cars, bridges and ore unloaders. To act as a brake the motor must not only absorb the stored energy of the moving parts, but must also exert additional torque to overcome the driving effect of the load. For instance, when applied to an elevator, the dynamic brake must stop the armature and usually the moving load, which tends to drive the motor as a generator so that more torque is required than that necessary to absorb the stored energy of the rotating parts.

Dynamic braking is often used, in addition, to control the speed of moving objects, such as lowering the load on cranes and hoists, and controlling the speed of trolley cars or trains descending a grade.† In such cases the brake is used to exert a retarding torque, the speed remaining constant, so that the energy absorbed is much less than if the load were stopped. Though this form of braking requires the development of less torque than in raising the load, the torque extends over a much longer period, and therefore causes increased heating of the motor.

A shunt motor, lowering a load on an elevator or hoist is often driven by the descending load above its normal speed, thus delivering energy back to the line. An induction motor operates in much the same way when driven above synchronous speed.

The connections and apparatus used for dynamic braking depend largely upon the form of motor employed. One of the early devices for braking was the so-called "disc" or "eddy current" brake. The eddy currents, however, were very slight, the principal braking being due to the mechanical friction between the revolving

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*See the JOURNAL for January '09, Vol. VI., p. 31.
†See article by Mr. Wm. Cooper on "Regenerative Control of Single-Phase Railway Motors"; Proc., A.I.E.E., Aug., 07, Vol. XXVI., p. 1469.

discs and stationary members. These brakes were applied about 1893 or 1894 to trolley cars and trouble was experienced with the brake freezing fast, causing the wheels of the car to "skid." For this reason, these brakes were not a success. It is possible that they would be satisfactory for industrial purposes where the motor is geared directly to the load, but recent developments have shown more convenient methods for applying the braking effect and this particular device has not been further developed.

Both alternating-current and direct-current motors can be made to exert a retarding effort by reversing the current through the motor and inserting sufficient resistance to reduce the torque of the motor to the desired amount. An induction motor with a wound secondary may be taken as an example. By sending current through the primary of the motor so as to exert a torque opposed to the moving load and adjusting the resistance in the secondary circuit of the motor, so as to control this torque, a braking action is obtained, of any amount up to the maximum torque of the motor. A direct-current shunt motor can be operated in the same way. Alternating-current motors can also be retarded by applying direct-current to the primary winding. This produces an inverse slip when the motor is revolving. If the motor is running at full speed, the application of direct-current will give the same torque and the same characteristics as if the motor were at rest and the primary connected to the alternating-current supply. With direct current in the field of the motor, the decrease in speed will cause a decrease in slip, and, if the resistance in the secondary of the motor is properly adjusted, a uniform retarding effort may be obtained.

The most common form of dynamic braking is in connection with direct-current motors. It consists in connecting the armature of the motor in a closed circuit with a resistance and adjusting the amount of this resistance. This resistance is sometimes used for heating as in trolley cars, and often the same resistance used for acceleration can be used for braking.

Limitations.—The most important limitation to the use of dynamic braking is the heating of the motor. During braking, the motor is doing work which causes heating, the same as during its active operation as a motor. Therefore, in selecting the proper size of motor, the effective heating due to dynamic braking should be added to the heating during its active cycle as a motor. In many cases this adds materially to the size of the motor necessary for the work. In arranging a motor for dynamic braking, care should be

exercised to prevent the voltage of the motor from exceeding a safe value. Should the motor be running at a speed in excess of normal value with normal field strength, it is evident that the voltage would be in excess of the normal voltage in the same ratio as the abnormal speed of the motor to its normal speed.

In stopping a direct-current motor and load by means of dynamic braking the active voltage of the armature is relied upon to cause a current to flow through a closed circuit. As the speed of the armature decreases, this voltage will also decrease, so that at rest no retarding torque will be available. Therefore, a dynamic brake cannot be used for bringing the moving object to a full stop, where the load is exerting an active torque on the motor, such as the de-
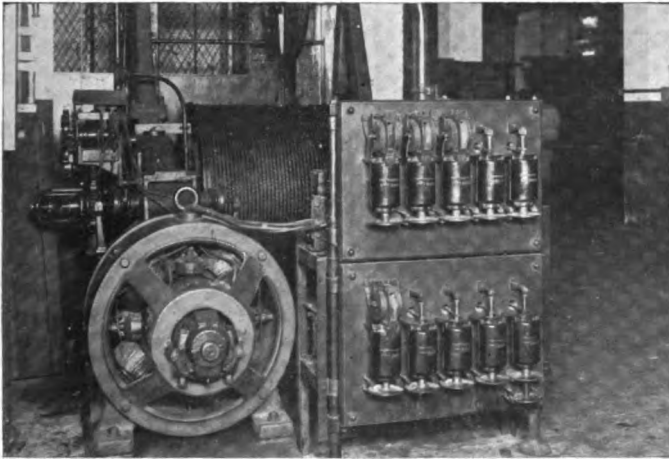
FIG. I—ELEVATOR MOTOR WITH CONTROL ARRANGED FOR DYNAMIC BRAKING

scending cage of a skip hoist. A simple form of mechanical brake, connected in the control circuit so as to operate automatically, is ordinarily used.

The use of a motor as a generator requires additional electrical connections, which add to the complexity of the controller.

Many forms of dynamic braking require considerable judgment on the part of the operator so that the application of dynamic braking has been largely restricted to such arrangements as those lending themselves to automatic control. For instance, the reversing of a motor with resistance in circuit is open to considerable objection, as it is hard to make this method sufficiently automatic to prevent abuse

by a careless operator. The use of a direct-current motor on a local closed circuit is the easiest method to render the operation automatic and therefore is the one universally used.

Advantages—The principal advantage of dynamic braking is the saving in wear on the apparatus. In retarding the load, either the motor must be used as the retarding element, or a friction brake must be employed. The friction brake, as the name implies, is dependent upon friction, which in turn wears away the materials upon which this friction is exerted, and must be renewed at more or less frequent intervals. If the motor is properly selected, the only wear and tear which actively deteriorates the apparatus is the burning of the contacts on the switch gear. These are usually much more easily renewed than the friction surfaces of a mechanical brake.
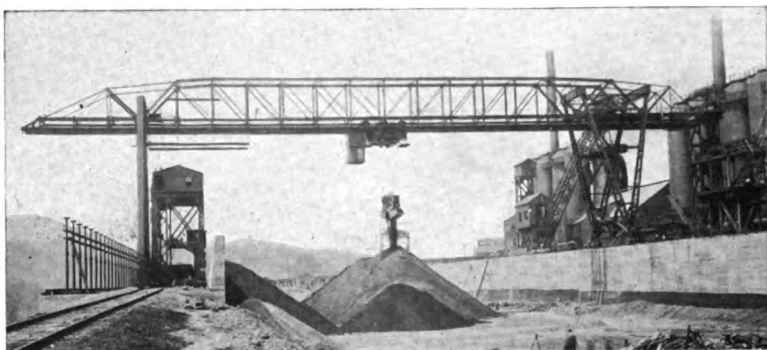
FIG. 2—ORE BRIDGE WHERE LOAD IS LOWERED BY DYNAMIC BRAKE METHOD

Further, the energy dissipated in lowering a load through a considerable distance is such that the mechanical brake must, of necessity, be very bulky, but by using a direct-current motor the external resistance can be placed in a convenient position and made amply large to dissipate the energy.

The speed of a descending load can be controlled very readily by means of dynamic braking and with very little effort on the part of the operator. The adjustment of the dynamic brake for special retardation and also for stopping is dependent entirely upon the line voltage, which is usually maintained constant within at least a few percent of its normal value, whereas the friction surfaces of a mechanical brake, even under the best conditions, are subject to some variation. The mechanical brake must be used for the final stop, but the accuracy of this stop can be maintained much better by the

use of a dynamic brake for slowing down, and a friction brake for making the stops only.

PRESENT INDUSTRIAL DEVELOPMENT

Up to the present time alternating-current motors have met with very little application as dynamic brakes. In one or two notable instances direct-current has been applied to the primaries of the motors for the purpose of bringing them to rest; in these cases, however, the motors were very large, and direct current was readily available. Many instances are undoubtedly to be found where the motor is reversed with resistance in the secondary element and used in this way for retarding the load and bringing the apparatus to
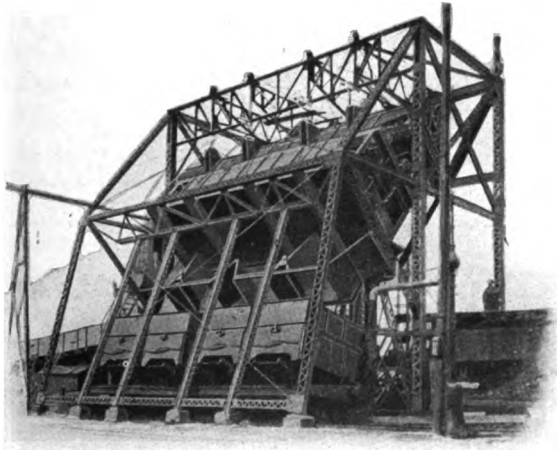
FIG. 3—CAR UNLOADER IN WHICH THE MOTOR CONTROLLERS ARE
ARRANGED TO GIVE DYNAMIC BRAKING.

rest. Such an arrangement adds but little to the complication of the controller, although it may involve the addition of one or two more resistance notches and some additional resistance. When this method is used, it is necessary to figure the resistance for dissipating the energy due to braking, as well as the energy due to acceleration; so that it is not safe to use, for this purpose, a resistance designed only for acceleration without giving due consideration to the heating introduced by braking. If the voltage of the motor is low a large amount of heat energy must be dissipated in the resistance and it may become very bulky under such conditions.

Direct-current motors are used for dynamic braking in a great variety of applications. Fig. 1 shows an elevator ·controller ar-

ranged for dynamic braking in connection with a shunt motor. The controller is made up of a number of electrically-operated switches. Some of these switches are for reversing the motor, others for controlling acceleration, and the additional switches are for the control of the braking.

An ore bridge equipped with direct-current motors is shown in Fig. 2, where the load is lowered by the use of the dynamic brake method. In this case the controller is arranged for lowering by throwing it on the first notch to give the load a start in the downward direction; the remaining notches of the controller connect the motor as a generator through resistances and vary its speed. Many large cranes are equipped in this way. The difference between the ore bridge and a Gantry crane is largely in the application and the details of the apparatus. Large mine hoists and skip hoists also employ this method of braking. A coal and ore car
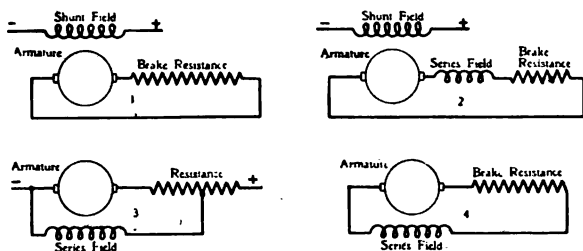
FIG. 4

handling apparatus is shown in Fig. 3, in which the control includes the use of dynamic braking.

METHOD OF CONNECTION AND CONTROL

In Fig. 4, diagram 1 shows a shunt motor connected for dynamic braking with the field across the line. Diagram 2 shows the same connections for a compound motor. When the work required of the motor during braking is small a compound motor may be used, the shunt field only being connected in circuit during braking action. For heavy loads both shunt and series field must be used.

In some cases a shunt motor has been used for lowering a load and the speed of the descending load controlled by varying the strength of the shunt field. This is advisable when the descending speed is considerably in excess of the hoisting speed, as the weakening of the motor field permits increase of speed without having the voltage of the armature exceed normal value.

When series motors on hoists, cranes, and similar apparatus are used for dynamic braking, where the load drives the motor in a positive manner, it is advisable to connect the series field as a shunt across the line during the first part of the braking operation to make sure that the motor builds up as a series generator. Diagram 3, Fig. 4, shows such a connection. Here the armature and series field are in shunt together and in series with a limiting resistance across the line. When the motor is at rest a connection of this kind exerts sufficient torque to start the load in a downward direction. After some speed has been obtained, the motor can be disconnected from the line; diagram 4, Fig. 4, shows the arrangement of circuits. In disconnecting the motor from the line, care should be taken not to open the connections between the series field and armature. Therefore, in passing from connection 3 to connection 4 the negative line is simply disconnected from one side of the circuit and a portion of the resistance together with the positive line is disconnected from the other side of the loop, thereby leaving a local closed loop, including the series field and the remaining part of the resistance.

COST

The cost of operating a motor as a dynamic brake depends largely upon the additional cost for the equipment. The fact that the motor, under certain circumstances, will return power to the line, is of little value in reducing the operating expenses, as this period is generally very short and usually it is necessary to operate the motor over a closed circuit containing resistance, as the speed is not such as to permit using the line as a return circuit. If the line is used as a return circuit, care should be taken that there is sufficient load in the line to consume all the power generated by the motor.

The field for dynamic braking is rapidly widening and the increased application of motors, particularly motors of larger sizes, is causing the use of dynamic braking to become more and more necessary; and as the subject is better understood, it is believed that many new applications will be discovered, in which the increased durability obtained by this method will effect great saving in operation.

EXPERIENCE ON THE ROAD

TWO-PHASE—THREE-PHASE TRANSFORMATION USING AUXILIARY TRANSFORMER

A. R. SAWYER

A METHOD is being used by a local power company similar to that explained in the article and editorial on "Three-Phase—Two-Phase Transformation by Standard Transformers," in the JOURNAL for December, 1908, in which three standard transformers are utilized to obtain three-phase current from a two-phase, 2 300 volt circuit for the operation of three-phase, 460 volt induction motors. This method has been used with entirely satisfactory results for about a year and a half.

This company had been supplying power by the two-phase system and decided to change over to the three-phase system, and at the same time overhaul and improve their water power plant, which was running part of the time in parallel with a steam plant about one-half mile distant. The company had a contract to furnish 220 volt direct-current power to a local company. As soon as the decision was made to change from two-phase to three-phase, the patrons of the company were required to use motors of the three-phase type in all new installations. Moreover, many of the two-phase motors were replaced by three-phase motors, so that, for a time, it was necessary to furnish a continually increasing amount of three-phase power from two-phase machines. In addition to this, after the plant was changed it was necessary to keep several two-phase motors in operation to drive some 220-volt, direct-current generators located at the power house; thus, in the year and a half during which the change was made, power was transmitted both ways through the transformers: i. e., some of the time the two-phase machines were running as motors, and some of the time as generators. It was the desire of the manager to avoid special transformers, as they would not be apt to be of use after the change was completed.

Two standard transformers were selected, of suitable capacity for the motor load, and, in addition, a third transformer of about fifteen percent of the capacity of one of the main transformers and of the same primary voltage. In the standard method of three-phase—two-phase transformation, it is necessary to use an 86.6 percent tap on the secondary winding of one of the transformers in order to obtain balanced three-phase voltages. In the present method the desired

voltage relations are obtained by bucking the primary voltage of one of the transformers by means of an auxiliary transformer. The connections are shown in Fig. 1, in which *A* and *B* represent the main transformers, and *b* represents the auxiliary transformer. The two primary coils of each transformer are connected in series for the 2 300 volt two-phase pimary voltage; the two secondary coils of transformers *A* and *B* are connected in series for the secondary three-phase voltage with a ratio of transformation of five to one, while the two secondary coils of transformer *b* are connected in multiple so as to oppose the primary voltage of transformer *B*, the
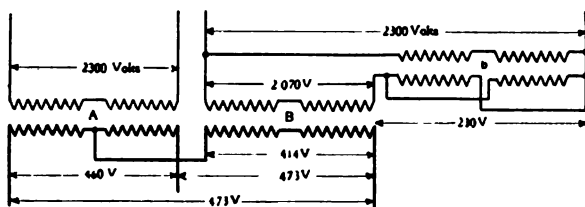
FIG. 1

ratio of transformation being ten to one. One secondary terminal of transformer *B* is connected to the middle point of transformer *A*, and approximately balanced three-phase voltage is obtained from the three remaining secondary terminals. The exact voltages are given in the diagram. The three-phase unbalancing amounts to less than three percent, which is, of course, entirely permissable for induction motor operation. This system has been used for synchronizing two-phase and three-phase machines, as well as for transmitting power in both directions.

A DEFECTIVE MAGNETIC CIRCUIT

R. H. FENKHAUSEN,
Chief Electrician, Risdon Iron Works, San Francisco, Cal.

THE action of a 10 kw, 110 volt, direct-current generator direct-connected to a vertical engine baffled the engineer on a certain government ship. The generator would only build up to 90 volts with the engine running at maximum speed and all the field resistance out, and each small increment of load caused further drop in voltage until the lamps on the circuit were barely visible, although the engine speed remained constant. The generator was carefully tested for reversed series fields, bad contacts, etc., but beyond an apparently excessive air-gap, nothing out of the ordinary

was noted. The engineer stated that the trouble dated from the last overhauling received by the engine, at which time the shaft had been raised to equalize the clearance in a new cylinder that had been installed, no adjustment of the connecting rod being possible. Upon receipt of this information the engineer was asked how it happened that the armature was concentric with the bore of the field after raising the shaft. He gave out the startling information that he had inserted brass distance pieces between the halves of the field frame. As these were nicely fitted and painted over they had not been noticed when examining the machine. The double break in the magnetic circuit together with the already large air-gap were enough to make any self-respecting machine act queerly. The shaft was lowered, the brass liners removed from the field, and the connecting rod taken to a forge shop and lengthened, after which the set ran as well as ever.

A REVERSED FIELD COIL

A series wound four-pole crane motor of the consequent pole type having but two field coils, burned out its armature. The armature which was of the wave wound type was completely rewound. The field coils were untaped, but as they were uninjured they were retaped and replaced in the motor. The repairman was cautioned to be sure both field coils were replaced in the machine so that the polarity would be correct in order that consequent poles might be created on the other two poles. The motor exerted no torque when current was applied, and although the connections were carefully gone over no errors were found. The repairman stated that he had tested the polarity of the fields with a compass and found them correct and, as he was a careful man, his statement was accepted, until the writer happened to pick up the compass and noticed that the north end pointed to the south. This gave us a suspicion as to the trouble, which was as follows:

The repairman fully excited the motor fields and brought the compass close to the upper pole piece which indicated "N." He then quickly dropped the compass to the lower pole, and the powerful field reversed the polarity of the needle before it could swing around, causing a false indication. After one field was reversed the motor ran correctly.

THE JOURNAL QUESTION BOX

238—RELAY FOR POWER STATION TELEPHONE RINGING CIRCUIT— Would it be possible to use an electrolytic rectifier to obtain direct current for operating a telephone ringing circuit in our power station, alternating current being obtained from a grounded bridging telephone circuit extending over ten or 15 miles and having on it about 15 phones with a magneto ringer at each instrument? It is proposed to operate a local ringing circuit from a 125-volt exciter circuit means of a relay, by connecting an incandescent lamp in series with the gong in the local circuit of the relay. Each phone has a different number of rings as a call and the relay bell must articulate these distinctly. The bell magnet is made up of two 1 000-ohm coils. Thus far we have not been able to obtain a rectifier of the proper capacity and arrangement to give satisfactory results in this direction. A. S. E.

The most effective arrangement would probably be found to be the use of an alternating-current relay in which the main essential feature is the use of a thoroughly laminated magnetic circuit. The difficulty with the electrolytic rectifier is that, instead of improving the operation of the relay, it would tend to increase the vibrating effect in the contact maker, because, instead of the electro-magnets of the relay being supplied with current of the frequency of the ringing circuit, the rectifier would eliminate every second alternation of the current and the resultant uni-directional current would be intermittent or pulsating. The use of a polarized relay, such as is employed in some telephone systems, would

also make it possible to operate directly on the telephone ringing circuit without a rectifier. With each alternation of the current the armature of such a relay is attracted first by one pole of the magnet and then the other, and thus contact is obtained on the secondary circuit of the relay, thereby making distinct signals possible. A further means of obtaining a positive and uninterrupted contact for the local ringing circuit would be to provide a spring contact similar to that used on electric bells. A third scheme which might be found effective in giving clearly defined signals would be to saw a slot in the end of the core of each pole of the electro-magnet of the relay in order to put a copper band around one-half of the end of each core. These bands should be soldered at the joint in order to insure a complete low-resistance electrical circuit; they would act as short-circuited or damping coils, the effect being to cause a lag in the magnetism of one-half of the core of each pole behind that of the other half. This would tend to give a constant pull on the armature, which is the condition required.

H. W. B. & H. M. S.

239—SELECTION OF METER CAPACITIES—How are the capacities of voltmeter, ammeter, wattmeter, polyphase integrating watt-meter, and series transformers determined for a three-phase, 2 200-volt, secondary voltage circuit to operate a 350 hp motor; and also, how is the power-factor of the motor determined? M. T. C.

The total power in watts delivered to the motor, over a balanced three-phase line, assuming 100 percent power-factor, is $\sqrt{3}\,E\,I$, where E is the e.m.f. between two lines and I is the current in one line. Three other quantities must be taken into account

to determine the maximum current, namely: power-factor, efficiency, and maximum overload. Thus the current in each line at the stated overload, *O. L.,* is expressed by,

$$I = \frac{746 \times hp \times (1 + O.L.)}{\sqrt{3} E \times P\text{-}F. \times Eff.}$$

A reasonable overload to allow on the ammeter is 50 percent. Efficiency should in this case be interpreted as the ratio of mechanical output to electrical input *in the primary.* Efficiency and power-factor at the maximum overload depend on individual conditions; but, assuming 80 percent power-factor and 90 percent efficiency, the current would be:

$$\frac{746 \times 350 \times 1.50}{1.73 \times 2\,200 \times 0.80 \times 0.90} = 143 \text{ amperes(approx)}$$

Full scale reading on the ammeter should be a round number, and in this case, therefore, should be about 150 amperes. Series transformers should also have a primary capacity of 150 amperes. The secondary current of the transformers should be adapted to the ammeter and wattmeter. Usually these meters take about 5 amperes for full deflection. The shunt transformers should have a ratio of approximately 2 200 to 110, to suit the voltmeter and wattmeter. The voltmeter should have a full scale reading considerably above normal voltage—say 3 000 volts; its calibration depends on the shunt transformer ratio. The wattmeter should have a scale allowing approximately 50 percent overload, so that its capacity (which should take account of motor efficiency) would be,

$$\frac{746 \times 350 \times 1.50}{0.90 \times 1\,000} = \text{approximately } 500 \text{ k.w.}$$

The calibration depends on shunt and series transformer ratios.

The capacity of the integrating wattmeter is calculated in practically the same way as that of the indicating wattmeter. If the integrating meter is required to be very accurate, it should not be on the same series transformers as the other meters, on account of the introduction of inaccuracy of ratio of these transformers where they are connected to several instruments in series. This inaccuracy is particularly noticeable when the current is small. If the integrating meter is connected to its own series trans-

formers it is not always necessary or desirable to take account of overload, because there is no definite limit to the capacity of an integrating meter as there is to an indicating wattmeter; and therefore the meter may carry an overload without difficulty. The advantage of neglecting the overload is that the meter is more accurate on light loads if its capacity is smaller. There is, of course, no necessity that the full load of an integrating meter should come out in round numbers, as is the case with indicating meters, because there is nothing on an integrating meter to make it apparent when it is carrying exactly its rated full capacity.

The power-factor may be determined most readily by the use of a power-factor meter. If this meter is not available, the power-factor may be found by the method described in No. 193 in the JOURNAL for January, '09.   H. W. B.

240—ACTION OF METERS ON REVERSAL OF POWER—A motor-generator set is intended for use in delivering either alternating-current or direct-current power according to the varying demand made upon the station at different hours of the day. Integrating wattmeters are permanently connected on each end of the set so as to run forward at a given end when that end is acting as a generator and backward when it is acting as a motor. Should both meters read correctly at all times under these conditions? If not, please state what features in each instrument will prevent such correct readings.   F. F. S.

By reference to an article in the JOURNAL for October, 1907, Vol. IV, p. 584, on "Metering Commercial Circuits," by Mr. H. Miller, a description will be found of the methods of correction for friction, frequency, etc., in one of the standard types of alternating-current wattmeters. If such a meter is operated on reverse direction of power it is evident from this description that, while the recording mechanism will operate without difficulty in the negative direction, the error at light loads will be double that which would occur if there were no such correc-

tion. Hence, in order to operate a meter under such conditions it is advisable to have the meter calibrated for the average light load condition, that is, without friction compensation. There will be no difficulty whatsoever for other conditions of load than that of light load, accuracy of registration or subtraction being in either case well within the ordinary percentage of accuracy of the meter. The same principle is involved in regard to the operation of the direct-current meter; the light load inaccuracy, however, being considerably greater than that of the alternating-current meter. Hence, in this case a calibration without friction compensation should also be made in order to average the light load inaccuracy. For ordinary conditions of load other than of light load the direct-current meter will also give reasonably accurate registration or subtraction, as the case may be.   W. B.

241—ADJUSTMENT OF INVERSE TIME ELEMENT RELAY—A polyphase inverse time element relay is connected to a circuit carrying from 60 to 75 amperes per phase. The ratio of transformation in the series transformers is 80 to 5 amperes. It seems to be impossible to vary the time of tripping on this relay. The spacing of the contacts is ½ inch and variation of the weights on the disc of the relay does not prevent its tripping the circuit breakers instantaneously on short-circuit. Please give information as to the cause.   A. W.

The time element of this relay, as the name implies, depends on the overload. The relay should operate in ½ second with the maximum weight on, with a current of 12 amperes. If more than this current flows in the relay as, for example, on a short-circuit, or if less than the maximum weight is used, the time is still less. The purpose of this relay is to introduce a time element in case of an ordinary overload, but in case of *excessive* overload (which is equivalent to a short-circuit) the action should be practically instantaneous. The time may be increased somewhat by increasing the spacing

of the contacts to about ¾ inch. If it is desired to introduce a time element, independent of the overload, a definite time limit relay should be used. A polyphase overload relay having a definite time limit action is described in the JOURNAL for March, 1908, p. 174, and is also referred to in the July, 1908, issue, p. 409. A time limit relay for use in connection with an overload relay is described in the JOURNAL for June and August, 1908, pp. 351 and 464 respectively. This latter relay could be used with the inverse time element relay to add a definite time element to the operation of the main relay.   H. W. B.

242—NOISE ON TELEPHONE LINE PARALLELING TRANSMISSION SYSTEM—Will you please advise what can be done to avoid static electricity on our telephone line? We have 32 miles of line, 17 of which parallel a 33,000 volt, high-tension transmission line. The telephone circuit is carried on the same poles as the transmission circuit and about five feet below on the opposite side of the pole, with transpositions every eight poles. The telephone line is very noisy during stormy weather.   O. H. H.

Noise during stormy weather is probably due to leakage rather than static, such as would result if the wires were in contact with twigs or branches of trees or other objects, or if the bottom parts of the insulators were by chance in contact with the poles so that during wet weather the moisture would give a leakage path for the current from the telephone wires. If there is continuous trouble from noise it may be due to static leakage in the instruments, as few telephones are sufficiently insulated to withstand high potential static current. If the spans are exceptionally long a noticeable humming may result, due to the wind; this can be remedied by inserting a little support between the two wires to prevent vibration or by placing an "anti-hummer" at the end of each long span. There is not sufficient information given to make a positive and definite answer possible, however. The most important thing is to keep the lines

free from grounds and leakage. If there is positive evidence that the trouble is due to static current, this can be eliminated by connecting each line to the ground through a condenser of about two micro-farads capacity and a graphite pencil of about 20 000 ohms resistance in series; placing these where they may receive frequent attention, preferably in the neighborhood of the cause of the disturbance. One such set would probably be sufficient, as the telephone circuit parallels the transmission line for only 17 miles. If condensers are not available, fair results should be gained by the use of an ordinary saw-tooth lightning arrester in place of the condensers, the spark-gap being adjusted as close as possible without the teeth touching, care being taken to keep the gap free from an accumulation of dust. If the phones are operated on the bridging system, it would also be possible to relieve the line of static current by simply connecting the center of the bridging ringers to the ground through a small resistance pencil; this, however, has the disadvantage of burning out the ringers if for any cause the telephone line becomes charged with high potential.   J. S. J.

243—IMPROVED REGULATION WITH DECREASE IN POWER-FACTOR— Referring to the article on "Drop in Alternating-Current Circuits," in the JOURNAL for April, 1907, it is evident from the data given in the table on page 229 that, under certain conditions of reactance, resistance and power-factor in transmission lines, a decrease in drop and improved regulation will result from decrease in power-factor. This is apparently the case in the first three lines of the table, while, in the major part of the table the opposite is the case. Please explain how this can be.

M. O. S.

In the article on "Limiting Capacities of Long Distance Transmission Lines" in the JOURNAL for February '07, Vol. IV., pp. 79-80, will be found an explanation of the above phenomenon. In the table, page 80, however, the ratio between reactance and

resistance is not taken as low as that given in the table on page 229, referred to in the question; and therefore the effect on the total drop is not as marked in the former as in the latter. The manner in which different ratios of reactance and resistance affect the line drop may be further shown by reference to Fig. 243 (a), which is simply an extension of Mershon's Chart. (See March, '07, Vol. IV., pp. 139-140.) Two cases have been assumed: First—that in which the smaller triangle, *DCB*, represents a condition similar to that indicated in the first three lines of the table on page 229, viz., a condition in which the reactance is relatively small and the resistance relatively large. To show the effect upon the
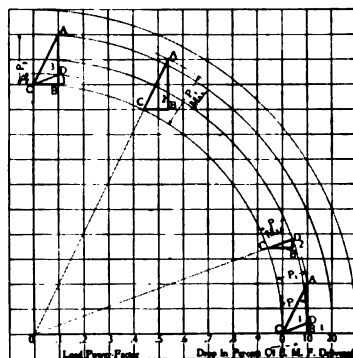
FIG. 243 (a)

regulation three critical power-factors have been chosen which represent the following conditions of load: (a)—Load of 100 percent power-factor; (b)—Load of such a power-factor that the total drop is a maximum (*i. e.*, the line *OC* and the line *CD*, which is the resultant of the resistance and reactance factors, lie in the same straight line); (c)— Load of zero power-factor. From these three conditions of power-factor it will be seen that : (1) The total drop increases with increase in power-factor; *i. e.*, at high power-factor the drop is controlled almost entirely by the resistance volts; (2) —The drop is maximum when the power-factor of line and load are the same. Second—The second case (represented by the larger triangle

ACB), indicates a condition similar to that to be found in the latter part of the table on page 229, viz., one in which the reactance is relatively large as compared with the resistance. In this latter case the total drop increases with decreasing power-factor up to the critical value shown in position 2 of the triangle *ABC*. C. P. F.

244—THREE-PHASE — TWO-PHASE TRANSFORMATION WITH DELTA-CONNECTED TRANSFORMERS — What are the relative merits of the methods of transforming from three-phase to two-phase by means of two "T"-connected transformers, and three delta-connected transformers in which the three transformers are tapped at the proper points, intermediate between their terminals, to give the desired 90-degree or two-phase relation of e.m.f.'s?
A. W. B.

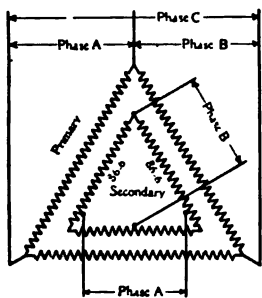The method using two transformers is represented by vector diagram

FIG. 244 (a)

and diagram of connections in the JOURNAL for October, '07, p. 598. The proposed method using three transformers connected in delta, is shown in Fig. 244 (a). The former method is more efficient. The latter method is probably satisfactory as a make-shift connection where, for example, it is desired to obtain an increase of capacity over that available by the use of two transformers in the ordinary method. The currents in the different windings vary considerably. In specially designed transformers the cross-sections of the different conductors could be adapted to the cur-

rents, thus reducing the capacity required; but, if standard transformers are used in which the cross sections of the conductors are uniform throughout, then in order to avoid overheating in spots, sufficient capacities must be used to take care of the full-load currents occurring at these points of maximum heating. Transformers that would handle 100 kw single-phase would give 87 kw capacity each with the ordinary T-connection and approximately 78 kw with the delta-connection considered herein. Further disadvantages in the delta-connection lie in the fact that three transformers instead of two are required, and having a larger aggregate capacity; also, the two secondary circuits are interconnected in a definite and not completely symmetrical manner, whereas, in the T-connection the two secondary circuits are inherently independent but may be interconnected in any desired manner.
E. C. S.

245—SOUND - INTENSIFYING DEVICE FOR GRAPHOPHONE—One of our representatives recalls having been present at a demonstration at The Electric Club some three or four years ago, of a device for intensifying sound in large phonograph work, in which a compressed air outfit was used to intensify the sound reproduced by means of a talking machine, the effect of the device being not only to increase the volume of sound, but to eliminate the troublesome scraping noise commonly noticeable in such machines, and giving remarkably perfect reproductions of the human voice and musical instruments. Can you give us any information regarding this apparatus?
F. M. N.

The apparatus in question was devised by the Victor Talking Machine Co., the essential apparatus being a graphophone outfit, a small alternating or direct-current motor of about one-fourth hp capacity direct-connected to a rotary air pump, and a small storage tank. A "gridiron" air valve was connected with the stylus of the graphophone so that vibrations set up by the record disc oper-

ated the air valve controlling the supply of compressed air in such a way that the volume of sound coming from the bell of the graphophone was increased. F. R. K.

246—OVERLOADING OF TRANSFORMERS
—In an installation of a 1 000 hp pumping motor operated from step-down transformers on a 13 200-volt, 60-cycle, three-phase circuit, lightning recently caused one of the transformers to burn out and at the same time burned out a connection on one of the primary leads. After this it was noticed that one of the transformer leads became very hot. The transformers are connected in delta. Would an open circuit such as that noted above cause either of the transformers to be overloaded? E. F. B.

Without a diagram of connections it is impossible to state definitely as to the conditions involved in the difficulty referred to. We believe, however, that this question will be found to be covered by question No. 160 in the JOURNAL for October, '08. For further information which may throw light on the subject see also the following: Questions Nos. 21, 26, February, '08; 91, June, '08; 96, July, '08, and 162, November, '08.
H. C. S.

247—METHODS OF STUDYING HIGH POTENTIAL STRESS—Please give some suggestions and methods for the study of potential stress in high-tension transformers (100,000 to 150,000 volts) at the point of breakdown. Please give references to literature on this subject. J. Y. Y.

See the transactions of the International Electrical Congress held at St. Louis during the Exposition of 1904, and the transactions of the American Institute of Electrical Engineers for 1904. See also paper on "Line Constants and Abnormal Currents in High Potential Transmissions," by Mr. Ernst J. Berg, Trans. A.I.E.E., September, 1907, p. 163. Such points as the effect of ionization

of the air on the breakdown point of insulators, terminals, etc., the effect on the strength of the insulation of distributing the potential stress in the insulation of the high-tension terminals by the introduction of alternate layers of insulating material and tin foil, thereby producing a condenser effect (see paper on "Condenser Type of Insulation for High-Tension Terminals," Trans. A.I.E.E., March, 1909, Vol. XXVIII, p. 233); the effect of shape and outline, rounding of edges, etc., on the breakdown strength of insulators, terminals, etc., and the feasibility of high potential air tests of complete transformers to determine points of weak insulation, may be considered. The points of high potential stresses may be determined experimentally by observation in the dark, as they will be found to glow or show "static" at these points. A. B. R.

248—PROPER SECONDARY VOLTAGE FOR WELDING STEEL—In welding steel tubes 2¾ inches in diameter and having 3-16-inch walls, a transformer giving from three to four volts on the low-tension side is used. Some difficulty is experienced in obtaining perfectly sound welds, and there always appears to be a burned spot usually where the first contact is made, which makes a leak in the tube. Is it probable that a change in voltage would make possible stronger and tighter welding. J. J. F.

We presume that you are using what is known as the incandescent, or Thompson, method of welding. The ends of the tubes should be true and smooth, and there should be a uniform contact around the entire circle of the tube when the current is turned on. If, under these conditions, trouble is experienced, we believe it can be remedied by reducing the voltage to about 0.9 to 1.5 volt. It is imperative that the source of power be free from noticeable fluctuations of voltage. It is apparently immaterial whether 60-cycle or 25-cycle current is employed.
C. B. A.

Transformers in Parallel

One of the most common practices in the use of electrical apparatus is the connecting of transformers in parallel. There is, however, among many of those who use transformers, no clear and definite idea of the fundamental elements which determine the division of the load. Exhaustive mathematical or complex diagrammatical solutions are apt to obscure rather than bring out clearly the simple and fundamental elements in the problem. As in the operation of most electrical apparatus there are a few fundamental factors. There are other factors, usually of secondary importance in ordinary apparatus, the consideration of which is necessary only when special refinements or unusual types of apparatus are employed.

The article by Mr. J. B. Gibbs on the "Parallel Operation of Transformers," in this issue of the JOURNAL, sets forth in a clear and simple manner the fundamental factors which determine the division of current between transformers operating in parallel. He presents the simple physical relations, and then illustrates them by simple diagrams. The circulating current between the transformers, which is sometimes used as the basis of discussions on this subject, is not directly considered. The problem is divided into two parts; the first takes up the relative currents in the two transformers, and the second the effectiveness with which the two transformers together act in supplying current to the line. It is found that the relation between the currents in the transformers depends upon their relative impedance, and that the sum of the two currents may be equal to or greater than that in the line, depending upon the respective ratios between resistance and inductance. It is found, however, that this latter condition is of minor consequence unless the transformers differ widely in the ratios of resistance and inductance. It follows, therefore, that the impedance of the transformers is the controlling element.

The magnetizing current as a factor has been considered by Mr. Gibbs as of secondary importance, and has not been taken into

consideration. The effect of magnetizing current is to increase the inductance of a transformer. There is a "leakage field" between the primary and secondary coils due to current in the primary alone as well as to currents in both coils. If, however, the magnetizing current is small, and further, if the magnetizing currents of the different transformers which are to be connected in parallel do not differ greatly, the magnetizing current will have but trivial effect upon the division of the load. It may be observed, furthermore, that the transformer which has the lesser rating is apt to be the one which has the higher percentage magnetizing current. Consequently, its impedance will be higher than it would be if its magnetizing current were smaller, and it will carry a slightly less proportion of the load than it otherwise would carry. This is not apt to be serious, however, for even a fairly large percentage of the load of a small transformer shifted to a larger one will increase the load upon it in much less proportion.

The present article shows not only the method of determining the division of the load between the transformers, but also the importance of attention to the characteristics of transformers which are to be connected in parallel. This becomes of greater consequence as transformers improve in quality and are built with small impedances which may, however, differ widely from each other. Two transformers of equal normal capacity, having equal copper losses of, say, one percent, and inductances of three percent and six percent, respectively, would operate independently to give under ordinary conditions of service approximately the same regulation, but would, if connected in parallel, divide the load so that one would carry nearly twice the current carried by the other, although the sum of the currents in the two transformers would exceed that in the line by less than one percent.

It is obvious that the division of load between the transformers depends upon the total impedances between the bus-bars, including with each transformer its connecting wires and any devices through which the current may pass. Hence, the impedance of a transformer circuit may be increased by the insertion of resistance or inductance in its primary or secondary lead wires. In general, a suitable choke coil in series with the transformer which needs more impedance will secure a satisfactory adjustment of current.

It may be further noted that, when the resistance and inductance ratios are unequal, the phases of the currents in the two transformers are not the same, so that two transformers may carry equal

currents and still not deliver equal amounts of power to the circuit. Hence, a wattmeter with its series coil in circuit with only one of the transformers will not measure half of the power. It will be more or less than half, depending upon which transformer is selected. CHAS. F. SCOTT

The National Electrical Code

The meeting of the Underwriters' National Electric Association held in New York, March 24th and 25th, was notable for the very few changes made in the existing code. A new set of rules was added covering the construction and installation of circuit breakers for certain classes of work, but outside of this there was practically nothing new added to the code. This condition of affairs should be very gratifying both to the underwriters and to all who come in contact with the code, as manufacturers, contractors or others, as it indicates that the rules embodied in the code at the present time are reaching a point where radical modifications are not necessary. The gradual decrease in the number of important changes in the code from year to year, combined with the very few changes required this year, has resulted in a recommendation, by the electrical committee of the National Board of Fire Underwriters, that the regular meeting of the committee be held biennially, instead of annually as heretofore.

Another feature of this meeting which is worthy of mention and which should be very gratifying to all concerned was the announcement that the municipal authorities of the city of New York have decided to adopt the National Electrical Code in their territory as governing electrical installations, only such additions being made as are required from the municipal standpoint and covering other matters than those directly concerned with the fire hazard. This carries with it a single inspection in place of a double inspection as heretofore, most of the work being done by the authorized representatives of the underwriters and their inspection certificate being accepted by the municipal authorities. Some other cities had previously taken this action, while still others have the double inspection with rules which in some cases are not uniform and often contradictory. It is to be hoped that the time is not far distant when a similar action may be taken by all the large cities having municipal inspection, so that the inspection and examination of electrical apparatus with relation to the fire hazard will be uniform throughout the United States.

Following the meeting of the Underwriters' National Electric Association was held the annual meeting of the National Conference on Standard Electrical Rules, this conference having representatives from all the national engineering bodies interested and also from the various Underwriters' Associations and from the large manufacturing interests. At this conference a matter of very considerable importance was discussed, this being the question of rules relating to the life hazard. This question had been referred by the Underwriters' National Electric Association to the National Conference with a view of ascertaining their opinion in regard to printing certain rules already in the code and which relate chiefly to the life hazard—as, for example, the grounding of the neutral point of distributing transformers, and certain rules in relation to theater wiring—with a note stating that these rules were life hazard rules and, therefore, would not necessarily be enforced by the underwriters except in so far as they might affect the fire hazard. It was the consensus of opinion of the conference that these rules should be printed with this explanatory note, and further action was taken by the appointment of a committee to bring in a report as to the advisability of securing the co-operation of the underwriters in promulgating additional rules or suggestions with reference to the life hazard. Mr. Goddard, secretary of the Underwriters' National Electric Association, stated that he thought there would be no objection to the printing of such rules or suggestions in the code for general distribution, provided they did not interfere in any way with the rules governing the fire hazard. It is certainly to be desired that municipalities, contractors and others installing electric wiring, use uniform and approved methods for safeguarding human life as well as for the prevention of fires from electrical causes.

C. E. SKINNER

Electric Locomotive Design

At no time in the history of electric traction has the design of electric locomotives received so much attention as it is attracting at present. The increased power required in heavy electric traction, together with the somewhat unsatisfactory results obtained with the older forms of locomotive, are contributing to this. Most of the electric locomotives now running have motors of the enclosed type, suspended from and geared to the driving axles. This is similar to tramway practice; but whereas in the latter, only small motors are needed and these, in any case, must be below the

floor line of the vehicle, with electric locomotives large heavy motors are required, and there is no particular reason why they should be confined to the space below the usual floor level of cars. The wear on tire flanges and rails on railways, when motors of from 100 to 200 horse-power are suspended from each axle, indicates that re-consideration of the method of application of electric motors in heavy traction work is desirable. This wear is undoubtedly due to the low center of gravity which results when motors are mounted on the trucks at about the same height above the rails as the axles. To a certain extent, also, the short wheel bases for bogie motor trucks, which have been used in some cases, contribute toward the aggravation of this evil. Various methods of spring suspension of the motors, with or without spring driving, have been tried with the object of overcoming these difficulties, but without decided success.

It is a matter of common knowledge that in the early days of steam locomotive design many engineers held the opinion that a low center of gravity would conduce to safety. With the weak track construction then in use the fallacy in this argument was quickly brought to light. Locomotives constructed with very low centers of gravity (in one case the boiler being placed below the driving axle) when running delivered severe blows to the track which resulted in accidents and derailments. With proper spring suspension and a relatively high center of gravity, the oscillations set up in a moving locomotive take the form of downward pressure on the rails through the medium of the springs. The blows are thus cushioned and gradually absorbed.

It is curious that much the same mistakes have been made in electric locomotive design. Several locomotives have been constructed with very heavy motors suspended low down, and in some cases with their armatures rigidly mounted concentric with the axles. It was thought that this construction, having no reciprocating parts, would be very satisfactory, but in practice it was found that severe stresses were set up in the permanent way.

It seems quite probable that heavy electric locomotive design will shortly undergo a complete revolution. Full advantage will be taken of the absence of reciprocating parts in the motors. The features to be aimed at are these: 1—That the only part of the locomotive not completely spring supported shall be the wheels and axles, and any connecting rods used in conjunction therewith. 2—That the center of gravity of the machine shall be raised to, say, about one and one-tenth times the width of the gauge. 3—That all

the heavier parts of the locomotive shall be placed longitudinally within the length of the driving wheel base, so that no heavy masses will be at either end of the locomotive. 4—That the motors shall be rigidly fastened to the main frame of the locomotive. This, together with their raised position, will make the motors much more accessible, and they may be of the partly open type, thus allowing better ventilation. Forced ventilation of the motors is very likely to become a distinctive feature of the modern locomotive.

The features mentioned above indicate that motors of much larger capacity than those now in use will be built, since the restrictions as to overall dimensions will be greatly relaxed when once the motor is removed from the immediate neighborhood of the driving axle. It becomes obvious that with this construction the connection between the motor and the driving wheels will be made by connecting rods, so as to allow full freedom of motion between motor and drivers. Whether any intermediate gearing is used or not will depend on the particular requirements of each case. It is certain, however, that the construction outlined above will enable electric locomotives to be constructed which will have far greater tractive effort and power than any hitherto built, at a cost bearing favorable comparison with that of steam locomotives and at the same time giving a machine possessing admirable riding qualities and having a very low cost for maintenance.

The electrical problems involved present no serious difficulties, and the design of the electric locomotive of the immediate future is, therefore, largely a mechanical problem. Recent progress with the single-phase, alternating-current system, with its economical transmission and distribution of power, brings the working of heavy trains at high speeds over long distances well within the range of practical railway work. It now remains to co-ordinate the electrical and mechanical features of locomotive design more completely than has been done in the past.   A. C. KELLY

The Use of Electricity In Mines   The attention which has been given to the subject of the use of electrical apparatus in mines, by mine operators, engineering societies and legislative bodies during the past year, furnishes substantial evidence of the growing importance of electricity in mining operations. In some instances considerable opposition to the use of electrical machinery has developed. In most cases false

impressions had been gained through non-scientific theories with reference to the use of electricity in mines as a factor in some of the mine disasters. It may be that owing to the rapidity with which this form of power is supplanting others, improper applications and methods have been adopted. In many cases the introduction of electrical apparatus as a labor saver has been opposed by the mine workers, and any reason which they could give for trouble from this source has been used to the fullest extent to make it unpopular. It is certainly desirable that a uniform practice based on the best experience in this branch of electrical engineering be adopted as a means of safeguarding life and property in mines.

Suggestions have been made from time to time relating to this question, perhaps none more practical than those offered by Mr. W. H. Keller, Consulting Engineer, Charleston, W. Va., in his paper before the West Virginia Mine Operators' Association, relative to the bonding of tracks, installation of feed wires, location of signal lights and gongs, grounding of motor frames, etc.

Mr. W. A. Thomas, in his paper before the last meeting of the American Mining Congress, emphasized the necessity of some uniform action on the part of the various state authorities and the co-operation of the federal government in conducting investigations to safeguard the mining interests.

At this meeting of the American Mining Congress a resolution was passed authorizing its president to appoint a standing committee for the purpose of standardizing as far as possible and making recommendations concerning electrical practice in mine work; the committee to consist of one consulting electrical engineer, two representatives of manufacturers of electrical equipment, two representatives of labor organizations and two mine operators.

The policy of formulating safe and conservative practice by a representative committee of this kind is one of great promise as tending toward something of a non-partisan and non-political character which can safely be used as a basis for action in all states in which mining is a factor in their industrial development.

If questionable practices have been used, they should be eliminated; but, on the other hand, if any doubts expressed are not well-founded, the industry should not be made to suffer out of mere sentiment or prejudice. We think the plan being carried out by the American Mining Congress is most commendable. It is another evidence of the broad scope and worthy aims of that body in furthering the interests of the general mining industry of this country.

THE MERCURY RECTIFIER*

R. P. JACKSON

EVER since the introduction of alternating-current machinery there has been a demand for devices of various kinds for receiving power from an alternating-current circuit and delivering it in the form of direct current, for use in connection with apparatus that requires current of an undirectional nature. There are in use devices of the following types, differing widely in limiting capacity and characteristics, but all accomplishing, with various degrees of effectiveness, the purpose desired: Motor-generator; rotary converter; commutator type rectifier; switch and spark gap type rectifier; electrolytic valve rectifier, and mercury vapor rectifier.

The motor-generator is entirely general in its application, as the power is delivered to an alternating-current motor and by it transmitted through the shaft or belt to a direct-current generator. Any voltage, frequency and capacity for which motors and generators may be built and wound can be handled by a motor-generator set.

The rotary converter is essentially a motor and a generator combined in one machine, using the same field and armature material. Its principal limitation is that there is a nearly fixed ratio between the alternating and direct-current voltage.

A commutator type rectifier is a commutator run at a speed synchronous with the alternating-current supply and accomplishes a literal rectification by switching over alternate half waves so that they traverse the load circuit in the same direction.

Several synchronous switching devices involving the closing of relays or the breaking down of spark gaps, in such a way as to connect the load circuit to alternate parts of the alternating-current circuit so that rectification occurs, have been tried with somewhat doubtful success.

Electrolytic rectifiers have been designed which make use of a valve action manifested by aluminum in certain electrolytes. Aluminum in many different solutions will, under the action of a current, build up a film on its surface which permits current to flow

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*A paper presented before the Engineering Society of Western Pennsylvania and appearing in the Proceedings of the Society for December, 1908, page 459. Revised by the author.

in but one direction. Two aluminum plates may be so connected, through a load, an alternating-current circuit and a plate of some other metal such as lead or iron, as to deliver all the alternations or half waves to the load in the same direction. Because of the drop in the voltage caused by the resistance of the electrolyte and the more or less inevitable leakage of current in the wrong direction, the electrolytic rectifier cannot as a rule attain an efficiency at all high.
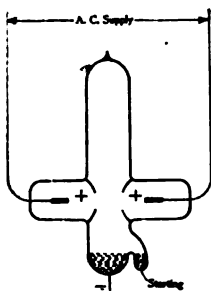

FIG. I

The mercury rectifier operates in a manner similar to the electrolytic rectifier, that is, by the action of electric valves. Nearly all metals have a tendency to suppress an alternating-current arc at the zero point of the current wave. Some of the metals, namely, zinc, cadmium and mercury manifest this characteristic in a very powerful degree. It is for this reason that a certain combination of zinc, cadmium and copper is used as a non-arcing metal in lightning arresters. Apparently this non-arcing or arc suppressing power is due to the sudden appearance of a resistance at the surface of the negative electrode as soon as the current ceases to flow even for an extremely short period. This negative electrode surface resistance is enormously increased with a condition of high vacuum, but ceases to exist as soon as a current has once started with a given electrode as continuously negative. A typical mercury rectifier bulb, or tube, is shown in Fig. 1. The two electrodes marked + are of iron, graphite or some substance that does not amalgamate with mercury. At the bottom of the bulb are two pools of mercury, one of which forms the negative electrode. The bulb itself is commonly of glass. At the start the negative electrode resistance exists throughout the bulb, that is, at all the electrodes, and would require anywhere from 6 000 to 25 000 volts to break it down so that current could flow.
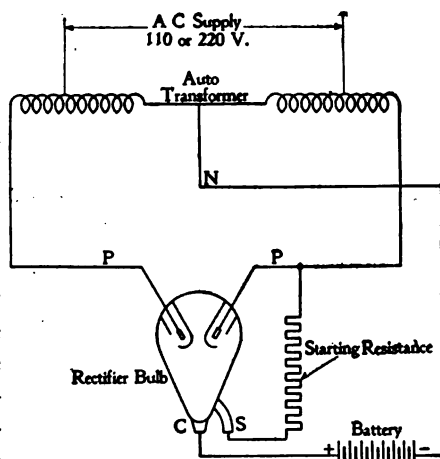

FIG. 2

The common and most reliable method of starting is to con-
nect some source of e. m. f. across the terminals of the two pools
of mercury.   When the bulb is tilted so that the mercury pools
flow together and part again, a spark is produced.   One end of this
spark or small arc will, of course, be negative, and when an arc is
thus started the negative electrode resistance momentarily disap-
pears.   Before it can re-establish itself the regular operation of the
bulb as a rectifier begins.   This regular operation consists of alter-
nate half waves of current passing first from one positive and then
from the other, to the negative or mercury electrode, and thence
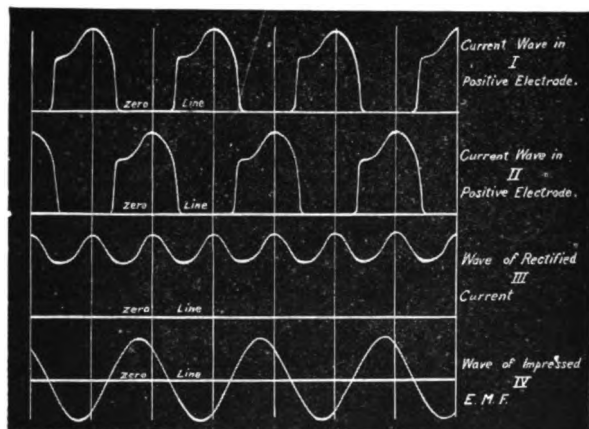out through the load and back to the middle or neutral point on the

FIG. 3

auto-transformer.   Fig. 2 illustrates the ordinary operating con
nections when charging a battery.   The starting resistance is only
connected in until the bulb has started.

The writer cannot explain in detail the nature of this valve
characteristic, caused by the peculiar film-like resistance at the sur-
face of conductors, but it is considered that the conventional as-
sumption that the actual flow of current is from the positive to the
negative electrodes may be incorrect.   Apparently the little parti-
cles called "electrons", described by J. J. Tompson as having a mass
of about 1/1000 part of a hydrogen atom, carry charges of nega-
tive electricity.   A current consists of a certain number of these
electrons moving as a stream in a conducting circuit.   Whether
these electrons are themselves charges of negative electricity or are
simply the carriers of such charges is immaterial for the present

consideration; the essential fact is that they can pass from a vapor to a solid conductor, but cannot pass without initial assistance from such a conductor to a vapor unless the pressure tending to cause them to do so is enormously increased. When once a start is made through the surface, however, the rest of the vapor path between the solid conductors is easily traversed. Consequently, to get a correct conception of the action the assumption regarding current direction must be revised; the actual current flow must be considered as upward from the negative or mercury electrode to the positive. Just why the electrons, or negative charges, cannot penetrate the surface of an electrode without assistance,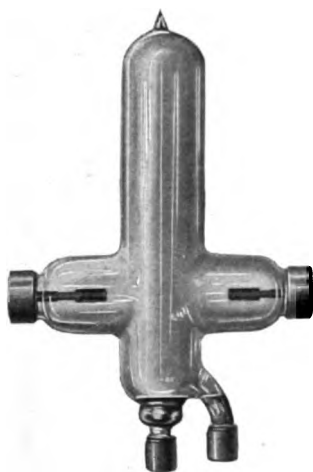 has been ascribed to surface tension, causing practically a skin or film, which has to be punctured. The fact that if the current is very small it is exceedingly difficult to maintain, indicates

FIG. 4

that the electrode skin resistance seems to reassert itself. Also, when the applied potential is high it is sometimes possible to start a current simply by shaking the bulb and breaking up the surface of the mercury into small ripples.

The total e.m.f. drop in a rectifier bulb ranges from about twelve volts up to forty or fifty. This drop is made up of about five volts or a little more, at the positive and about four volts at the negative, combined with a drop in the vapor path, dependent largely on the length and diameter of that path and also on the number of bends or angles which the path takes. An increase of vapor pressure increases the drop, but an increase of temperature operates in the other di-

FIG. 5

rection, to decrease the drop. All other gases than mercury vapor give a much higher drop than mercury vapor and their presence even in small quantities has this effect.

The current capacity of a bulb is dependent on the section and size of the leading-in conductors, especially of the platinum seals which carry the current through the glass. It is also dependent on the total cooling surface of the bulb, as there are limiting temperatures for good operation, and the only way to keep the temperature down is to give large radiating surface to the glass or to operate in oil. During operation, mercury vapor and also many small drops of
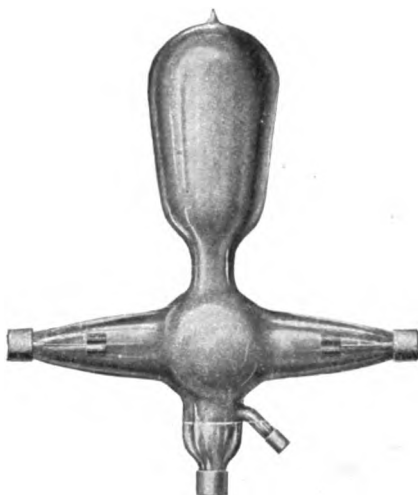

FIG. 6   FIG. 7

mercury are given off by the bright negative spot in the mercury which gather on the inner surface of the glass and condense into larger drops which run back into the pool. In so condensing the heat carried passes out through the walls of the bulb and escapes through radiation and convection.

The voltage which the bulb will sustain and deliver to the direct-current circuit is dependent largely on the length, narrowness and crookedness of the vapor path. A bulb has to be worked out so as not to permit even the smallest particle of mercury to spatter against or fall upon the positive electrodes, as if this happens, the negative electrode resistance is broken down at the point where such a drop impinges and the result is a short-circuit between the positives. From Fig. 2 it may be seen that such an

occurrence not only short-circuits the transformer but may permit a battery to feed back through the bulb and operate it the same as a direct-current mercury vapor lamp, with destructive effect on the bulb.

The relationship of the primary e. m. f., the current from the two positives and the total rectified current through the direct-current load is shown in Fig. 3. Fig. 4 shows a five to ten ampere bulb suitable for delivering 100 volts or less on direct current, and Fig. 5 shows a bulb for 30 amperes which is suitable for 300 volts or less. Fig. 6 represents a so-called high-tension bulb suitable for from four to seven amperes up to 3 500 volts, and is used for delivering current to series arc light circuits. Fig. 7 shows a 30 to 50 ampere bulb for 120 volts or less.
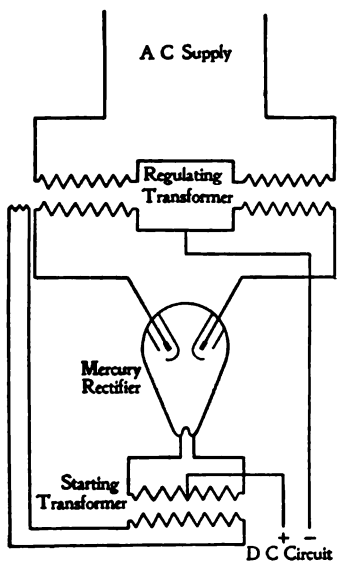
It will be noted from Fig. 3 that the direct current is not uniform, but is pulsating. If there were no reactance in the direct-current circuit, or its equivalent, the current would drop to zero at each point where it dips down and in reality the bulb would go out. By including a certain amount of reactance in the direct-current circuit, or its equivalent (properly placed in the auto-transformer) enough magnetic energy is stored during one-half wave to maintain the circuit from one position in the bulb until the current from the other has begun to flow. By

FIG. 8

giving certain values to this energy-storing reactance, a certain shape can be given to the "ripple" in the direct-current wave. As the current is reduced the ripple remains the same, but its average height above the zero line becomes lower. When the current becomes so low that the points of the ripple reach zero, the rectifier will drop out or cease to operate as the negative electrode resistance has been re-established. This ripple can, if necessary, be made very small, but at some loss in efficiency. It is exceedingly difficult, however, to reduce the direct-current value below two amperes, on account of the tendency of the negative electrode resistance to re-assert itself and stop the current altogether.

The current passes through the vapor in the bulb in a diffused

path, causing a general glow and this glow continues up to and around the anodes or positive electrodes. At the cathode, however, the current finds its way through at one small spot of great brightness. This spot is continually dancing around over the surface of the mercury, keeping that surface constantly agitated. Solid materials flash and give off sparks if by accident they become negative, and the mercury glows over its whole surface if it is used as a positive electrode; thus their entrance and exit characteristics are determined by the direction of flow of current and not by the materials composing the electrodes.

APPLICATIONS OF THE MERCURY RECTIFIER

At present the two principal uses for the mercury rectifier are for delivering direct current to constant-current series arc lamps, especially those of the metallic flame type, and for battery charging. In either case there is no objection to the somewhat pulsating nature of the direct current.

For series arc lighting a constant-current regulator similar to that used with the ordinary alternating-current constant-current system is required. Fig. 8 shows the typical connections. The pri-

FIG. 9

mary coils of this regulator are movable and counter-balance each other in such a way as to give a constant secondary current. The small starting transformer is provided, simply to produce a spark for breaking down the negative electrode resistance in one of the mercury pools. Figs. 9 and 10 show the external appearance of such an outfit combined with its panel containing switches, ammeter, tilting handle, etc. The rectifier bulb is contained in a box, shown in Fig. 11, which may be slid down in guides into the case, or tank, until the buttons on the bottom make contact with similar buttons on the soapstone base. The bulb, therefore, runs in the same
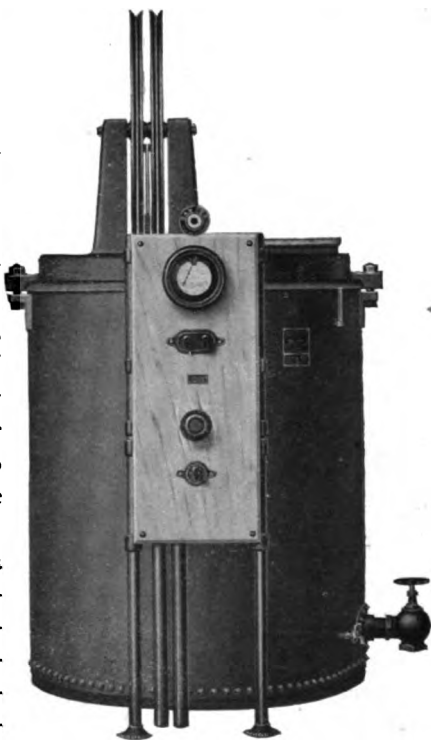
oil as the regulator, both for convenience in shortening up the high voltage wiring and to get the greater and more uniform cooling effect of the oil. Such arc light outfits are built in sizes from 25 to 75 lights in a single circuit and 100 lights if composed of two separate arc circuits.

·For so-called low voltage purposes the mercury rectifier has its widest application to the charging of automobile batteries from lighting service circuits. There is also considerable employment
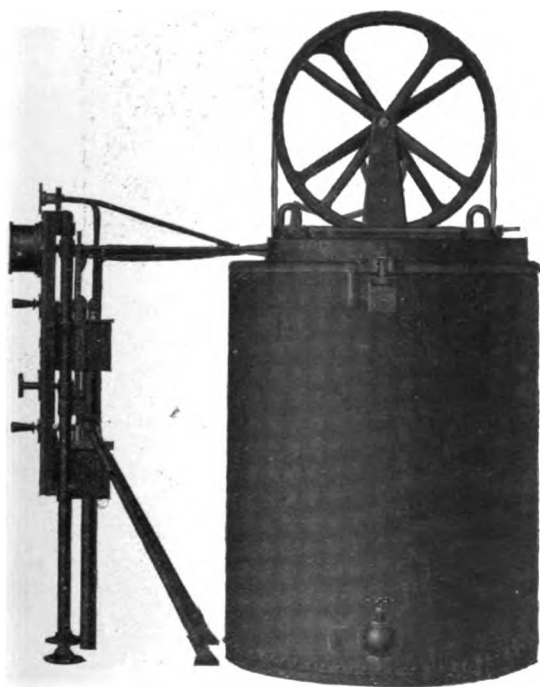

FIG. 10   FIG. 11

of rectifiers in charging the batteries of telephone substations and the batteries on Pullman cars for lighting purposes. Figs. 12 and 13 show an ordinary panel type outfit for battery charging, capable of delivering from 7 to 30 amperes to batteries of from 10 to 44 cells. Very few vehicle batteries have more than 44 cells, as that is about the maximum number that can be charged from an ordinary 110 volt direct-current circuit. There is no reason, however, why batteries of a larger number of cells should not be used if desired, as a rectifier could readily be made to charge 100 or 200

cells and a smaller current would be required in charging a battery
of a given power storage capacity.

In charging automobile batteries it is often convenient to start
the rectifier and be able to go away and leave it, permitting the
charge to be completed without further attention. This can be
accomplished by incorporating just the right proportion of react-
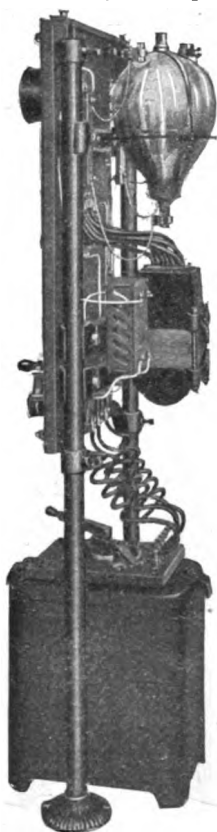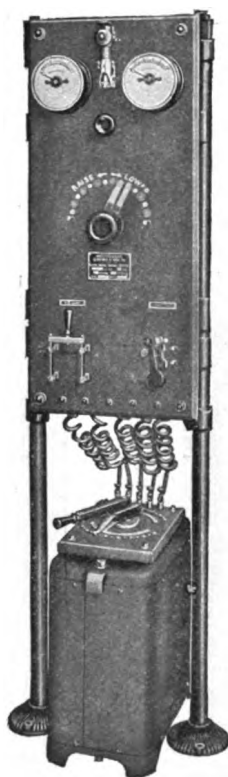

FIG. 12   FIG. 13

ance with the auto-transformer for each direct-current voltage to
give the proper drooping regulation curve to the outfit. Figs. 14, 15,
and 16 show such an outfit for battery charging. The various di-
rect-current voltages are obtained by the proper dial settings as
given by a table covering all the even numbers of cells within the
range of a given outfit. If for a certain number of cells the dial
setting gives 30 amperes at 2.1 volts per cell, the current will grad-
ually taper down in value to about ten amperes at 2.5 volts per cell
and at 2.55 volts per cell the current will be six to seven amperes

and the rectifier will drop out or cease charging. This drooping characteristic is not obtained by the use of resistance, which would consume energy, but by reactance, which simply slightly reduces the power-factor.

Some owners expect their battery charging rectifiers to operate during the portion of the night required for charging the battery and then drop out, not permitting the wattmeter to register the iron loss of the auto-transformer the remainder of the night. It should be pointed out that this may be possible in some cases, due to the quality of the meters used, yet in general, it cannot be assumed that the wattmeters will not record the iron loss of the auto-transformers. This iron loss ranges from 50 to 75 watts, depending on the size of the outfit and the primary voltage. As the capacity of these sets is approximately five kilowatts, the minimum loss, or 50 watts, would be one percent. Reliable intergrating meters will register on one-half of one percent. If the loss were 75 watts and lasted from midnight until morning it would only amount to about four cents per night. This is the price the owner must pay for not having to get up and open the primary switch, and at the worst, can make but a trifling difference in the total bill.
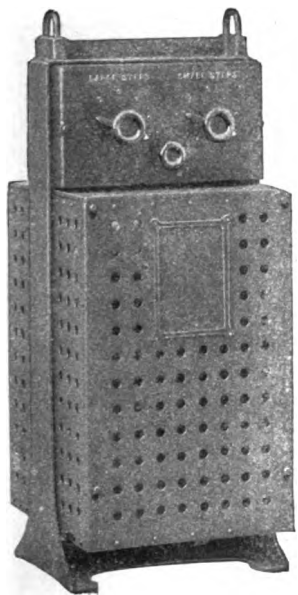
This should be understood; otherwise, when the owner finds his meter running slowly in the morning after battery charge has ceased he is likely to imagine that it is running up a large bill against him, which is not the case. The cost is about the same as though a single incandescent light had been left burning for four or five hours, or from the time the rectifier dropped out until the primary switch was opened.

FIG. 14

˟ On account of the characteristic of the rectifier, which permits the negative resistance of the cathode, or negative electrode, to re-establish itself after even an extremely short interruption of current, the rectifier will of course cease to operate if power is cut off the primary circuit even for the shortest possible interval. Where such an interruption is not likely to happen it is of no consequence, but where it is liable to occur, an automatic bulb tilting device can

be provided which will cause the bulb. to re-start at all currents above ten amperes, except when the dropping out is the result of the current becoming low at the end of the charge when the battery voltage has risen to a maximum. About fifty amperes capacity is as large as seems to be practicable in a single rectifier bulb, but there is no particular difficulty in paralleling two or more bulbs if each individual circuit is ballasted properly, to make the bulbs divide the load. A rectifier bulb has characteristics similar to an arc, and it is well known that two arcs cannot be made to run in parallel unless ballasted by resistance, or reactance, to make the

FIG. 15   FIG. 16

voltage over each arc circuit increase with an increase of current, and vice versa.

For telephone battery charging, the ripple or pulsating shape of the direct current must be reduced to such a degree as to prevent noise from being introduced into the telephone circuits. This is readily accomplished but requires various amounts of reactance in different telephone circuits. The reactance required also depends somewhat on the wave shapes of the generator supplying power.

Rectifiers are also made to supply direct current to the hand fed arc lamps of moving picture machines. For such purposes all

that is necessary is to close the carbons together and the rectifier starts automatically. The arc may be pulled out to suitable length; if the carbons are pulled too far apart the arc will break and the rectifier cease to operate. This method may be employed for stopping the outfit.

The life of the rectifier bulb is a matter of much interest to users of rectifiers and is, moreover, a matter on which definite information cannot be given. A great deal depends on the usage a bulb receives and also on the quality of workmanship in its construction. There seems to be no reason why a good bulb should not run within its rating for 3 000 to 4 000 hours. While some bulbs do reach such a life the methods of production are not sufficiently uniform to make the average bulb last nearly so long. Six or eight hundred hours is a good average life at present, though cases are repeatedly to be found where bulbs have run much longer. The actual final limit seems to be the disintegration of the glass by the long continued exposure to heat.

The battery charging set requires no inspection until the bulb finally goes out. After being properly connected, there is practically no attention required. There is nothing to deteriorate any more than in a service transformer. The arc light outfits simply require starting and stopping night and morning. There is no commutator, no bearings to oil, and there is nothing that can go wrong with it to cause destruction. There are no moving parts, no friction of any kind, everything is static, and there is nothing to deteriorate outside of the bulb itself, which of course has a limited life.

Unless supplanted by something still simpler and even more reliable, the mercury rectifier will undoubtedly cover a wide field in supplying power in small units from alternating-current circuits to those requiring direct-current. Before it can be made applicable to currents of 100 amperes or larger from a single unit, however, some very difficult problems must be solved.

PARALLEL OPERATION OF TRANSFORMERS

J. B. GIBBS

PERFECT parallel operation of two or more pieces of elec-
trical apparatus means that the common load divides among
the separate units in proportion to their rated capacity and
that the numerical sum of the currents in the separate units equals
the line current. In the case of transformers two conditions must
be fulfilled to produce this result: the ratio of high tension to low
tension turns must be the same in all units, and the voltage drop
from no load to full load must be the same in all units, both in
magnitude and in phase. The first of these conditions is obviously
necessary, for a difference in ratio causes a difference in secondary
voltage at all loads, and the transformer having the higher voltage
will, of course, carry the larger load.

The necessity of the second condition will be equally clear.
Suppose that there are two transformers having the same open
circuit secondary voltage, say 100, but one transformer has a full
load voltage of 96, and the other transformer of 98, i. e., at full load
one transformer has a drop of four volts and the other a drop of
two volts. If, now, the two are connected in parallel to a common
load equal to the sum of their rated capacities, the voltage at the
terminals must be the same in both, and will lie somewhere between
96 and 98 volts. The drop in the first transformer, therefore, will be
less than four volts, and the current must consequently be less than
full load. Similarly in the second transformer the drop will be
greater than two volts and the current greater than full load.

The impedance drop, or total drop in a transformer, is the re-
sultant of two components; the resistance drop, which depends only
on the ohmic resistance of the windings and is in phase with the
current; and the reactance drop, which depends on the magnetic
leakage between high tension and low tension sides and is 90 de-
grees out of phase with the current. This relation is shown in
Fig. 1.

When two transformers having the same percentage impedance
are connected in parallel, each will carry current in proportion to
its rated capacity, but unless the relative amount of resistance and
reactance is the same in both, the sum of the currents will be greater
than the current in the line. This is due to a phase difference be-
tween the currents in the two transformers, and may be explained
as follows:

Suppose that any two parallel circuits, *A* and *B*, Fig. 2, containing resistance and reactance are connected between an alternator and its load. The current will divide at *c* and flow through *A* and *B*. The current in each circuit will be numerically equal to the voltage drop from *c* to *d* divided by the impedance of the circuit, and will lag behind the voltage *cd* by an angle determined by the ratio of reactance to resistance. This angle is not necessarily the same for the two circuits, and the currents, therefore, are not necessarily in phase with each other.

A vector diagram showing this condition is given in Fig. 3, where *OE* represents the drop *cd* in Fig. 2; *OA* is the current in circuit *A* (equal to the voltage *cd* divided by the impedance of circuit *A*) and lags behind *OE* by the angle θ_a (whose tangent is the ratio of reactance to resistance in circuit *A*). Similarly *OB* is the current in circuit *B*, and lags behind *OE* by the angle θ_b. Evidently
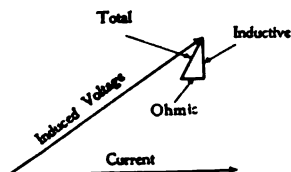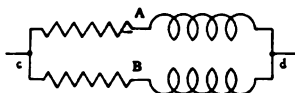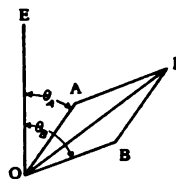

FIG. 1   FIG. 2   FIG. 3

then, if the ratio of reactance to resistance in circuit *A* is different from that in circuit *B*, θ_a will not equal θ_b, and hence *OA* and *OB* will not coincide in direction with *OI*, and their numerical sum will be greater than *OI*.

If the two parallel circuits be replaced by two transformers connected in parallel, the same is true. If the impedance of the two transformers, in percent, is the same, both will carry the same percent of full-load current; and if, in addition, the ratio of reactance to resistance is the same in both, the currents in the two transformers will be in phase with each other, and their numerical sum will equal the load current, giving perfect parallel operation.

If transformers will not divide their load correctly it is important to know which will carry the excess load and how great the excess will be; and this can easily be found by means of a diagram similar to Fig. 3. Data as to the resistance and reactance of transformers, if not at hand, can be obtained by measurement as follows:

Resistance—Measure the resistance of the high and low tension windings with the transformer at normal operating temperature. This is usually done by passing a direct current through the

winding and measuring the voltage drop. Reduce the resistance of the low tension winding to the equivalent high tension resistance by multiplying by the square of the ratio of high tension to low tension turns, and add the measured high tension resistance; the sum is the equivalent resistance of the transformer in ohms, referred to the high tension winding.

Impedance—The impedance is measured directly. The low tension winding is short circuited, and a very low voltage—from two to five percent of normal—is applied to the high-tension winding. The voltage is gradually raised until an ammeter in the circuit indicates full-load current in the transformer, when the voltage across the high-tension winding is read. This gives the impedance volts; and the impedance volts, divided by the full load high-tension current, gives the impedance of the transformer, expressed in ohms, referred to the high-tension side. If it is not convenient to adjust the current to the exact full-load value the measurement may be made at some other value and the voltage corresponding to full-load current may be found by direct proportion.

Reactance—The reactance is not measured directly, but is found from the resistance and impedance, the relation being:

Ohms reactance$=\sqrt{(\text{Ohms impedance})^2-(\text{Ohms resistance})^2}$.

The load diagram may now be constructed. Assume a line OE, Fig. 4. to represent the impedance voltage drop within the transformer. This line is used merely as a reference line, and its length is not important. Lay off from O on OE a distance Oa equal to the resistance of transformer A, and from a to the right lay off ac equal to the reactance of transformer A. Through O and c draw a straight line which will represent the phase of the current in transformer A, with reference to the impedance voltage OE. Similarly lay off Ob and bd equal respectively to the resistance and reactance of transformer B, and draw a line through O and d to give the phase of the current in transformer B. Now the current in each of two parallel circuits is inversely proportional to the impedance, therefore on Oc lay off a distance OA, equal to the impedance of transformer B, and on Od lay off OB equal to the impedance of transformer A, and complete the parallelogram OBDA. The diagonal of this parallelogram gives the phase of the load current with reference to OE. On OD lay off OI equal to the total load current, and resolve along Oc and Od to get OI_a and OI_b respectively. The lengths of these lines then represent actual currents in transformers A and B respectively, to the same scale as was used in laying off OI.

It will be noticed that the proportion between OI_a, OI_b, and OI is not changed by a change in the length of OI, also that no account is taken of the voltage on the load. It follows that the distribution of load between transformers in parallel is independent of the amount and power-factor of the load, if the ratio of transformation of the two transformers is the same.

When the currents in the two transformers are not in phase, the excess current—i. e., the excess of the sum of the currents in the two transformers over the line current—is obviously dependent upon the amount of the difference in ratio between the resistance and reactance in the two transformers which is, in turn, represented by the angle between the two currents, as shown in Fig. 4 by the angle AQB. With an angle of 90 degrees, which is the theoretical limit which would be reached if one transformer had resistance and no reactance, and the other had reactance and no resistance, and if the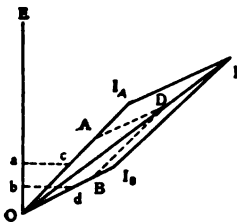 ohms resistance in one case equals the ohms reactance in the other, then the two currents would obviously be represented by the two sides of a square, and the total or line current by the diagonal. If the diagonal or line current have a value of 100, then each side would have a value of 70.5, and the sum of the two sides corresponding to the sum of the two currents in the transformers would be 141, giving an excess of 41 percent. If the angle between the two currents be 45 degrees, then the maximum possible excess will be eight percent. If the ratio between the resistance and reactance in one transformer be as one to one, and in the other transformer as one to four, corresponding to an angle of about 30 degrees, then the excess is approximately four percent. It will obviously be less than this if the ratio lie between the two limits of one to one and one to four. It follows, therefore, that unless the reactance of one of the transformers is less than its resistance the excess current will be relatively small. Hence, the differences in impedance will usually be found to be the controlling element in the division of current between transformers, and the matter of ratio between resistance and impedance is of minor consequence.

The essential characteristics with regard to the parallel operation of transformers may be briefly summarized with relation to transformers which have the same ratio of high-tension to low-tension turns and in which the magnetizing current is relatively

FIG. 4

small. (The magnetizing current has not been taken into consideration in the following statements, as its effect is trivial when the magnetizing currents are small.)

1—Two transformers with the same percent impedance—The current in the two transformers will be in proportion to their rated capacity; the sum of the currents, however, may be greater than the current in the line.

2—Two transformers having unequal percent impedances—The current in each transformer in percent of its rated full-load current will be inversely proportional to its impedance—e. g., if one transformer have two percent impedance and the other four percent impedance, the first transformer will carry twice as large a percent of its rated capacity as the second transformer will carry. The sum of the currents in the two transformers may or may not be equal to the line current.

3—Two transformers, each having the same ratio of resistance to reactance—The current in the two transformers will be in phase with the current in the line; hence, the sum of the currents in the two transformers will equal the current in the line.

4—Two transformers having unequal ratios of resistance to reactance—The currents in the transformers are not of the same phase; hence, their sum is greater than the line current. The excess current, however, will be small unless the difference between the ratios is large—for example, if the reactance of neither transformer is more than four times its resistance nor less than one time the resistance, then the excess current in each transformer does not exceed by more than approximately four percent what it would be if the ratios were the same in the two transformers.

5—Two transformers with equal percent impedance and equal ratio of resistance to impedance—The division of the current is in proportion to the rated capacity, and the sum of the currents in the two transformers is equal to the line current. This is the ideal condition.

In the foregoing five cases, the division of current, i. e., the ratio between the amperes in the two transformers, and the excess current, i. e., the excess of the sum of the currents in two transformers over the total current in the line, is independent both of the actual load upon the transformers and of the power-factor of the load current.

MECHANICAL CONSIDERATIONS IN THE APPLICATION OF ELECTRIC MOTORS TO INDUSTRIAL MACHINERY

C. B. MILLS

CONSIDERED from a mechanical standpoint only, there is little choice in point of reliability between a direct-current motor and an alternating-current induction motor. The direct-current motor armature has the mechanically undesirable commutator and brushes and, usually, a larger proportion of insulating material than the alternating-current rotor which, however, labors under the inherent mechanical disadvantages of a very small air-gap or clearance for the rotating element.

The particular method of application selected for any type of motor has more direct bearing on the durability and life of the motor than is commonly supposed. This can be appreciated when it is remembered that the revolving armature of any type of motor is composed of a great number of parts, coils of wire, etc., held together by bands or wedges and depending to a greater or less extent on fibrous or cotton insulating materials of little mechanical strength and, therefore, more susceptible to injury from jars and vibration than other forms of revolving machinery. It is important, therefore, when considering a motor application, to choose a method of connection which will tend to absorb or nullify these effects unless the motor has been designed with a special aim to meeting these conditions, as in railway motors, special mill motors, etc.

BELT CONNECTION

Wherever conditions will allow, belt drive should be considered, as the belt forms the most flexible connection between motor and load and is the best-known absorbent of mechanical shocks due to load variations. For ideal conditions the belt speed should be from 4 000 to 5 000 feet per minute, and the load per inch width of belt for good oak tanned leather, should not exceed values shown in the curves given in Fig. 1, which illustrate plainly the influence of speed in reducing the allowable effective load on the belt.

In general the load per inch width for single or light double belts should not greatly exceed 40 pounds for belt speeds under 4 000 feet per minute and should not exceed 32 pounds for speeds from 4 000 to 6 000 feet, which is the practical limit of working.

The total working pull on belt may be found from the following equation:

$$\text{Pull in pounds} = \frac{\text{hp} \times 33\,000}{\text{Belt speed in feet per min.}}$$

Belt speed in feet per min.=Pulley dia. in inches $\times 0.262 \times$ r.p.m.

For certain classes of service where belted motors operate in dusty locations, as in clay crushing plants, cement mills, flour mills, etc., the action of dust accumulations on the belt tends to reduce its pulling power 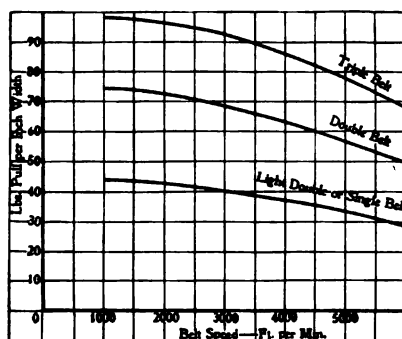and necessitate an increase in width of from 25 to 50 percent over that which would be satisfactory for ordinary conditions. Experience has shown that a four-ply treated canvas or rubber belt is approximately equal in transmitting power to a single or light double leather belt of good quality.

FIG. I—CURVES SHOWING PERMISSIBLE BELT LOADS AT VARIOUS SPEEDS

The maximum ratio between driving and driven pulleys should not exceed 6:1 for ordinary conditions, and the distance between centers will depend on the ratio, good proportions being approximately as follows:

Approx. Ratio.	Min. Distance Between Centers.
2:1	8 feet
3:1	10 feet
4:1	12 feet
5:1	15 feet
6:1	20 feet

All belts should have a normal lap on the pulleys of at least 160 degrees unless some form of idler pulley is used to increase belt contact. The use of paper pulleys allows a somewhat smaller degree of lap owing to the better adhesive qualities of this material, and for this reason is to be recommended for all small pulley drives.

It is not usually considered good practice to use heavy double belts of any kind on pulleys smaller than 15 inches diameter, as the abrupt bending of the thick belt over a small pulley soon opens the fibers and ruins the material.   ●

ROPE CONNECTION

On a par with belt driving in its effect on the motor can be placed rope drives of either the English or American system, and

many installations are at present using this drive for large motors. The English or separate rope system is a favorite in rolling mill or other work where large powers are transmitted and continuity of operation is especially desirable, while the American or single rope system is especially adapted to group drive from a large unit. For either system as large a rope as possible should be chosen, for economical reasons. The transmitting power of different sizes of manila ropes at different speeds may be taken from the curves in Fig. 2.

To insure reasonable life of the ropes, the smallest sheave over which the ropes run should be not less than forty-two times the diameter of the rope used. Lubricated core rope should be used, as the principal friction tending to destroy rope is between the fibers themselves and, owing to the action of centrifugal force, external lubricant will not penetrate the rope.
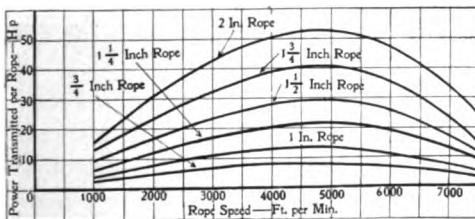

FIG. 2—CURVES SHOWING TRANSMITTING POWER OF ROPES AT VARIOUS SPEEDS

Considering the life of the rope alone, experience shows that the most economical speed is 4 500 feet per minute, and this should be used where cost of maintenance is an important factor.

Very small pulleys or sheaves, in general, and on induction motors in particular, should be avoided, as they necessitate heavy belt tension to transmit the power and invariably produce bearing troubles which militate greatly against efficient operation, and on induction motors with their air-gap clearance cause secondary troubles liable to damage the machine seriously.

Toothed Chain Connection.—In many applications where positive connection is desirable, a toothed chain, such as the Morse or Renolds type, offers a somewhat flexible and a very satisfactory method of motor connection. When the center distances between driving and driven shafts are too short for belts and too great for the use of gears, the maximum ratio obtainable with chain is approximately 6:1. As short a center distance should be used as possible owing to the expense of the chain. For the best operation, the chain speed should not exceed 1 500 feet per minute, as beyond this speed the necessary grease for lubrication is thrown off and the wear becomes excessive. It is also imperative that means be provided for

adjusting the sprocket center distances to take up the wear in chain and sprockets and keep same fairly tight. Chains work best when driving horizontally. The driving side should be on the bottom when distance is long and on top when distance is short or speed high. For certain very severe conditions spring center gear sprockets have been used and found very satisfactory in protecting the motor and increasing the life of the chain. Chain drive imposes a more severe strain upon the revolving parts of a motor than a belt drive and this fact must be borne in mind and should be properly discounted in the type and design of motor recommended for a specific application.

Gear and Pinion Connection.—Owing to its economic advantages as to floor space, etc., the trend of new development appears to be in the direction of direct geared applications, and it is where this condition exists that the greatest precautions must be taken to eliminate those undesirable factors which usually result in a rapid depreciation of the motor unless it has been designed with a view to fitting this particular application.

In general it has been found that where standard motors designed for belted service, have been used in general applications, driving roll trains, bending rolls, plunger pumps, glass grinding machinery, cement mill machinery, clay working machinery, coal and ore handling machinery, hoists, cranes, etc., etc., failure has been very frequent where the mechanical limitations of the electric motor were not properly understood and taken into account.

As an engineering proposition, the use of a standard commercial motor of over 20 horse-power with a pinion mounted directly on the motor shaft should be avoided wherever possible. Where service conditions demand a direct-geared connection, an ideal arrangement, and one to be used wherever possible, is to have the pinion carried on a short shaft in separate pedestals or other bearings; this shaft to be coupled to the motor shaft by some form of flexible or cushion coupling. This arrangement at once removes the motor from the destructive vibrations and hammering of the gears, allowing a lighter type of motor to be used, and, while somewhat more expensive than the common method of mounting the pinion directly on the motor shaft, the increase in cost is a cheap premium to pay for the practically absolute continuity of operation assured. It is especially applicable in many lines of industrial work where wear on the bearings of the driven mechanism is an unimportant item and where the motor bearings are liable to be neglected.

Where the above arrangement is not permissible and where

operating conditions are not too severe, an outboard bearing for the motor shaft beyond the pinion is to be recommended for motors of 20 horse-power and over, as this auxiliary increases by nearly 100 percent the resistance of the shaft to bending and the ability of the bearings to resist pounding out. As the chief cause of trouble on geared motors can be traced directly to the hammering and vibration due to the tooth impacts, the best practice demands that for commercial motors, where the pin is mounted directly on the shaft, speeds should not exceed 700 r.p.m. for motors above 20 horse-power, and for heavy work even this is too high.

The maximum pitch line speed at which cut metal gears should be run is approximately 2 000 feet per minute, and speeds higher than 1 200 feet are not to be recommended for best results, particularly where the pinion is mounted directly on the motor shaft.

Pitch line speed may be determined from the following equation:

$$P.L.S. = Rev. \times Pitch. \; Dia. \; in \; inches \times 0.262.$$

$$Pitch \; Dia. \; in \; inches = \frac{Number \; of \; teeth}{Diametral \; Pitch}$$

$$Pitch \; Dia. \; in \; inches = \frac{Number \; teeth \times Circular \; Pitch}{3.14}$$

As in ordinary motor drives the pinions are usually of forged steel, the strength of the gear only need be considered when figuring the size of gear required. The following table shows a ready means of determining the proper proportions of cast iron gears having more than 25 teeth to transmit a given horse-power, also the gear pitches preferable for motor drives.

TABLE I.—SHOWING VALUES OF HP PER INCH WIDTH FOR PITCH LINE SPEEDS ABOVE 1 000 FEET PER MINUTE.*

Hp to be Transmitted.	Preferable Diametral Pitch	Hp per Inch Width per 100 ft. per Min.
1 to 2	8	0.24
2 to 5	6	0.30
5 to 10	5	0.38
10 to 30	4	0.48
30 to 75	3	0.64
75 to 125	2 ½	0.76
125 to 200	1 ¾	1.10

*For cast steel gears the values in hp per inch width should be increased 2½ times.

For pitch line speeds from 500 to 1 000 feet per minute the above values of horse-power should be increased 50 percent, and for speeds up to 500 feet per minute should be increased 100 percent.

The minimum pitch diameter of motor pinion is approximately (2 x dia. of shaft) for ordinary cases, and the smallest pinion should not have less than 14 teeth under any condition.

EXAMPLE:—25 horse-power motor, 600 r.p.m., countershaft speed 100 r.p.m.

Diameter motor shaft at pinion fit=2½ inches.

Smallest pitch diameter possible=2×2½=5 inches.

From table of preferable pitches, pitch=4 inches.

Therefore, smallest number of teeth=4×5=20.

Pitch line speed=600×5×0.262=786 feet per minute.

Horse-power per 100 feet per min.= $\dfrac{25 \times 100}{786}$ =3.18.

From the table it is evident that horse-power per inch of width at this speed=0.48+(50 percent)=0.72.

Therefore, the proper face of cast iron gear= $\dfrac{3.18}{0.72}$ = 4.41, or, say, 4½ inches.

Proper number of teeth for gear== $\dfrac{600 \times 20}{100}$ =120 teeth.

Where cast iron gear faces figure out greater than seven inches, it will be economical to consider cast steel gears, as by their use the face may be made one-half the size.

When high speed motors must be used in geared-applications, experience has shown that rawhide pinions alleviate vibrations, noise, etc., to some extent, although not sufficiently to make unnecessary such precautions as should be taken where steel pinions are used. The value of the rawhide lies principally in its noiselessness of operation, especially where the rawhide is not shrouded, viz., where the design is such that the retaining brass cheeks are cut below the roots of the teeth. With such forms of pinion, pitch line speeds of 3 000 feet per minute have been used successfully on motors up to 50 horse-power. The strength of rawhide is approximately the same as cast iron, and this fact must be borne in mind when considering the use of rawhide pinions, as it will be evident that a steel gear cannot be driven to its full capacity by a rawhide pinion.

For the majority of motor applications, involute forms of cut

gear teeth are to be recommended, as this form does not require the maintenance of exact center distances demanded by other forms of teeth. Also, because this form has been adopted as standard by the majority of gear manufacturers under the Diametral Pitch System.

Cushion Couplings.—In many applications, such as air compressors, plunger pumps, etc., the motor is required to be coupled directly to an intermediate shaft which usually carries a pinion for transmitting power to other parts of the mechanism. Application of a motor to this service should be through a cushion coupling for best results, as with the usual forms of rigid coupling the shocks and vibrations from the gears due to the cyclical variations in the load are transmitted back to the motor and are very destructive to the revolving windings. Vertical motors driving centrifugal pumps through long vertical shafts should always be connected together by means of a flexible coupling that will allow considerable displacement in shaft alignment as, owing to the absence of gravitational forces in the plane of revolution, all vertical running motors and shafts are extremely sensitive and destructive vibrations are easily started.

Flange Couplings.—For applications where the motors have to deliver a practically constant torque and where there is little liability of shafts getting out of alignment, such as centrifugal pumps, blowers, motor-generator sets, etc., a flange or rigid form of coupling has been found entirely satisfactory. A careful investigation should always be made, however, of all factors liable to influence operation, as successful application of this form of coupling requires practically ideal conditions.

Foundations.—In many motor installations insufficient attention and care are bestowed on the motor foundation or method of mounting to insure satisfactory motor operation. This is particularly true of geared applications where motors are frequently found shimmed up with wooden blocks. This should not be tolerated, as it can be nothing else than unsatisfactory; rigidity of mounting or foundation being of extreme importance in geared applications.

APPLICATION OF AUTOMATIC CONTROLLERS TO DIRECT-CURRENT MOTORS—IV

CONTROL OF MOTORS IN STEEL AND IRON MILLS

D. E. CARPENTER

THE service requirements of motors and controllers in the steel and iron industries are more exacting than in any other application. The motors usually range in size up to about 250 horsepower at from 220 to 250 volts. The momentary overloads are often excessive. The operation of starting is repeated at frequent intervals, and in many cases full load is continually required alternately in reverse directions within very short spaces of time.

The controllers operating mill cranes and hoists, such as soaking pit cranes, ore bridges, etc., are subjected to especially hard service, which usually continues for twenty-four hours per day. The current requirements are often very heavy and the controller may be required to open circuits in which the current equals or exceeds the full rated capacity of the motor and controller.

Automatic magnet switch control is peculiarly adapted for such service. The ease and accuracy with which the rate of operation of the magnet switches for acceleration and reversals can be predetermined; the readiness with which stop motion limit switches can be applied; the flexibility in location of the controllers and motors with respect to the operator; the fact that several motors can be controlled by one operator, all combine to make this system of direct-current motor control almost ideal for steel mill service.

With automatic control, the motors and the driven machinery are fully protected from any injury resulting from careless or indifferent controller operation. The action of the magnet switches is started by the operator, after which they act automatically at a predetermined rate, bringing the motor up to full speed or reversing it quickly, but with perfect safety. With any device that must travel a given distance and then stop, such as traveling tables, ore bridges, car dumpers, ingot "buggies," etc., the attention of the operator is not required to stop the motor, since limit switches can be arranged to do this. In fact, for such operations as revolving the top of a furnace, magnet switch controllers can be arranged in connection with limit switches so that the motor will be automatically started each time a car of ore is dumped and stopped when the top has rotated through the proper angle. This insures an equal

distribution of burden in the furnace and thereby gives improved working conditions.

For quick stopping or reversing, dynamic brakes can be arranged for automatic operation by magnet switches. For example, in raising the screw-down of a rolling mill, the motor usually runs at high speed; when the screw reaches the upper limit of its travel quick reversal of the motor is necessary to adjust the rolls for the next ingot. Automatic magnet switches can be arranged to apply a dynamic brake for quickly stopping the motor without shock, excessive wear, or undue stress on any part. With this system of control, reversing the motor too quickly is impossible. The magnet switches act automatically in the order and at the rate for which they are adjusted, and the operator cannot hurry them except by changing the adjustments. The operations of reversal and starting, therefore, can be made as quickly as the safety of the motor and connected apparatus will permit. In other words, while rapid work is assured, the motor is protected from unnecessary and dangerous overloads.

Since the master switch and its connecting wires carry only the small current required to operate the magnet switches, the master switch is light, occupies comparatively little space, and can be placed in the most convenient location regardless of the location of the motors and controllers. This feature is of great importance in many installations where space is limited; for example, in the operating leg of an ore unloader. In mill service the operator can be located where he can easily see all the operations, and where he is free from the heat generated in the controlling resistance, while the

FIG. 1—AUTOMATIC MAGNET SWITCH
CONTROLLER FOR ROLLING MILL TABLE

controller and resistance can be installed near the motor, making the heavy leads very short.

The acceleration can be by voltage control, that is, by drop of voltage in the starting resistance, or by series relay. For many steel mill operations very rapid acceleration is desirable and the magnet switches are so connected that the delay in their successive opera-tion is only the time element of the switches. In such cases each accelerating magnet switch, by means of its interlocking contacts, connects the next one directly across the circuit, all closing very rapidly, but always in the same consecutive order.

Magnet switches for such service must be so constructed that they will close with a quick positive action and open with a snap. All switches required to break a circuit in which any considerable
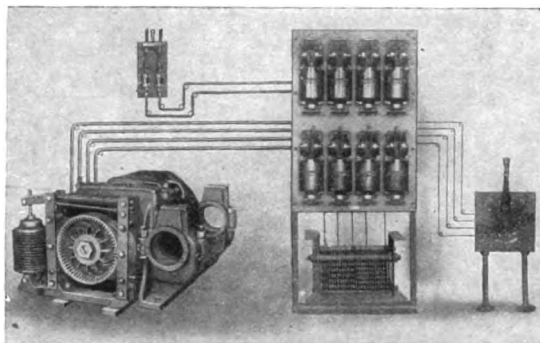

FIG. 2—TYPICAL INSTALLATION MAGNET SWITCH CON-
TROLLER WITH LINE SWITCH AND MASTER SWITCH,
IN CONNECTION WITH DIRECT-CURRENT MILL MOTOR
EQUIPPED WITH ELECTRIC BRAKE.

current is flowing should be provided with blow-out coils which will quickly disrupt the arc formed between the separating con-tacts; the wearing parts of the switch, contacts, arcing tips, etc., should be durable, simple and easy to repair.

Both the main and interlocking contacts should be so placed that accumulations of dust and dirt cannot interfere with their con-ductivity. In magnet switches of the type shown herewith the main contacts close under such strong compression springs that good contact is assured. For dusty places the interlocking contact surfaces can be made vertical, as in Fig. 7, so that dust will not be deposited on them.*

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*See also Fig. 10 of introductory article in the JOURNAL for Jan., '09, p. 27.

The connection diagrams, Figs. 5 and 6, show typical connections in simple form. Fig. 5 shows the connections of a five-point, eight-switch controller, with a two-point master switch. The four magnet switches in the upper row are for starting, and those in the lower row for short-circuiting the starting resistance in steps, i. e., for accelerating. Turning the master switch to forward position *1*, causes the two inside magnet switches in the upper row to close and start the motor with all resistance in series. Further movement of the master switch to position *2* causes resistance contacts R_2, R_3, R_4, and R_5 to close successively in the order named; each is delayed by drop of voltage in the starting resistance, thus making the rate of acceleration depend on the motor current. The motor and controller can be operated on either point of the master switch.
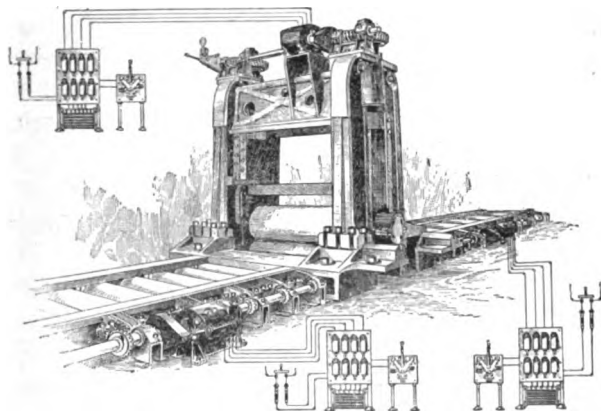

FIG. 3—TYPICAL INSTALLATION MAGNET SWITCH CONTROLLERS
AND DIRECT-CURRENT MILL MOTORS OPERATING ROLL TABLE

Reversing the master switch first opens the circuit to the two starting switches, causing them to open, and this action opens the circuit to the resistance switches which also drop open. Since the operating current of the starting magnet switches must pass through the lower interlocking contacts of the resistance switches, the motor cannot be started in either direction until all the starting resistance is in circuit. Consequently, however quickly the master switch is thrown from forward position *2* to reverse position *2*, two starting magnet switches and all the resistance switches first open, cutting all the starting resistance into circuit. The other two starting switches then close, followed by the successive closing of the resistance switches, each when the starting current has fallen to the

strength for which the adjustments were made. The reversal is thus made in the least possible time consistent with safety.

Fig. 6 shows the connections of a five-point, eight-switch automatic magnet switch controller with a five-point master switch. The connections are similar to those with a two-point master switch, except that in this case the operation of each resistance magnet switch depends on the positon of the master switch handle. With the master switch on the first point, two starting switches in the upper row close, connecting the motor across the circuit with all resistance in series. On the second point, resistance switch R_2 in the lower row closes; on the third point, switch R_3, etc. The master switch can be left on any notch or returned to the preceding notch with corresponding action of the magnet switches. If the master switch is advanced quickly to the fifth notch in either direction, the magnet switches will close in regular order, but the closing of each resistance switch will be delayed by voltage drop in the starting resistance until the current has fallen to a safe value. Likewise the sudden reversal of the master switch can work no injury to the motors on account of the automatic action of the magnet switches
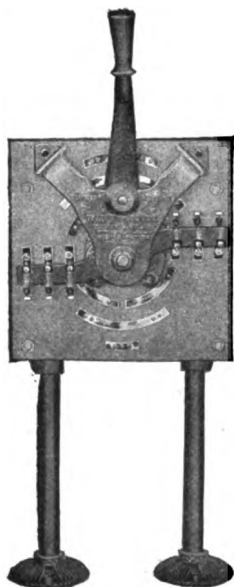
Many refinements in addition to those shown in the connection diagrams are possible. For example, a dynamic brake, an overload trip or circuit-breaker relay, an accelerating relay, etc., can be added. The control of hoist motors from the floor would sometimes be found to be a great convenience, as in lifting flasks in a foundry. With a magnet switch controller a drop switch can easily be arranged so that the operator on the floor can "inch" the hoist while watching the flask. On signal from the floor the crane operator will place the master switch on the first notch so that all the controlling resistance will be cut into circuit, thus giving minimum speed; after which the floor operator, by closing and opening the operating circuit of the starting magnet switches by means of the drop switch, can obtain the exact results desired.

In many hoisting processes a definite cycle of operations is con-

FIG. 4—MASTER SWITCH FOR AUTOMATIC MAGNET SWITCH CONTROLLER

tinually repeated. For example, a skip hoist is called into opera-
tion on the arrival of a car of material at the base; the skip is car-
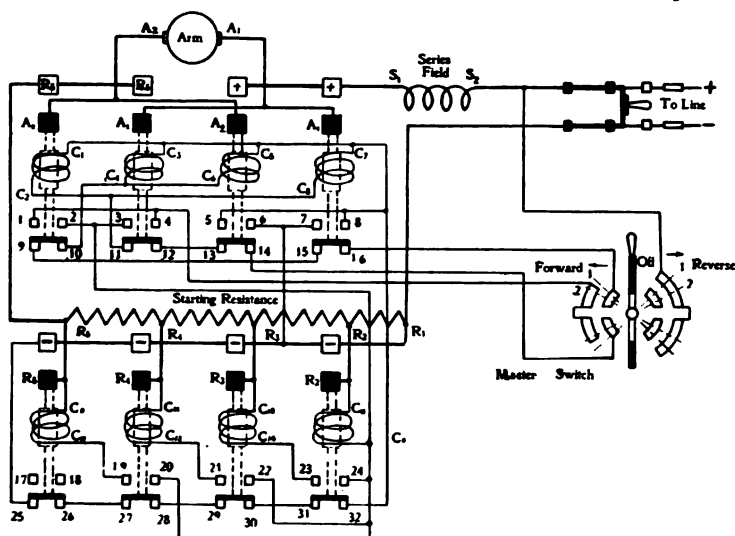

FIG. 5—CONNECTION DIAGRAM, FIVE-POINT EIGHT-SWITCH AUTOMATIC CON-
TROLLER WITH TWO-POINT MASTER SWITCH

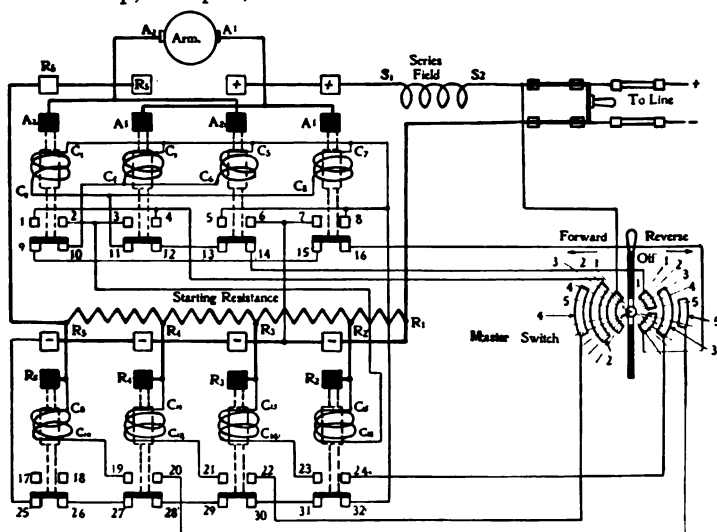ried to the top, dumped, and returned to the base for another load.

FIG. 6—CONNECTION DIAGRAM, FIVE-POINT, EIGHT-SWITCH AUTOMATIC
CONTROLLER WITH FIVE-POINT MASTER SWITCH

All such recurring cycles of operations can be performed auto-
matically by means of magnet switch controllers, with a great sav-

ing of time and expense and with the assurance that the perform-
ance will be reliable and accurate.

The controller shown in Fig. 7 is used with a compound-wound
motor operating a skip hoist at the Cornwall Ore Banks, Lebanon,
Pa. The shunt field relay prevents the closing of any of the mag-
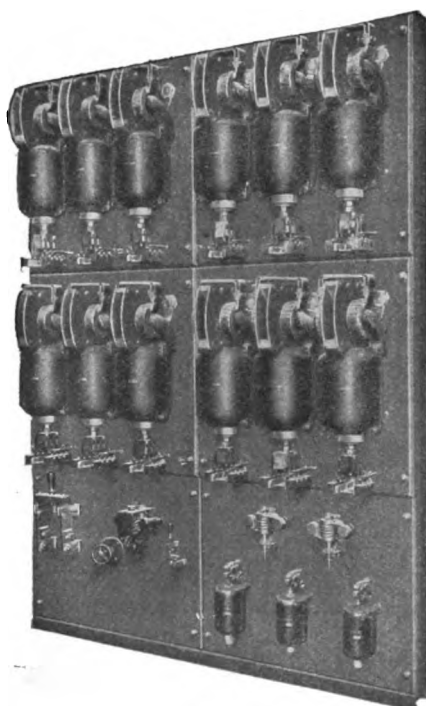net switches if the field switch is open or the field circuit is open at
any other place. The hoist,
or accelerating relay prevents
the magnet switches from
cutting out the starting resist-
ance too rapidly. The over-
load relay causes all the mag-
net switches to open if the
current is too large; this relay
is closed by means of a reset
switch. When the hoist ap-
proaches the limit of travel, a
geared limit switch driven di-
rectly from the hoisting drum
closes the circuit through the
fast speed relay, which at
once short-circuits the field
rheostat giving the motor full
field and reducing the speed.
Further movement of the
limit switch causes all the
starting resistance to be cut
into circuit, thus further re-

FIG. 7—AUTOMATIC MAGNET SWITCH CON-
TROLLER FOR OPERATING SKIP HOIST AT
CORNWALL ORE BANKS, LEBANON, PA.
On the panel are mounted twelve 1 000-
ampere automatic magnet switches and
below the switches, from left to right,
are a line switch, field rheostat, overload
relay with reset coil, field switch, shunt
field relay, hoist (accelerating) relay,
fast speed relay, brake relay and safety
relay.

ducing the speed, and finally
disconnects the motor from
the line, all by means of the
magnet switches. As soon as
the line connections are open-
ed, the counter-e.m.f. of the
motor causes the safety relay
to close the operating circuit

of a magnet switch, which immediately connects a resistance across
the armature terminals, forming a dynamic brake. This resistance is
actuated by the braking current, that is, the short-circuit current
through the armature and the brake resistance.

NOTES ON THE SINGLE-PHASE RAILWAY MOTOR

S. M. KINTNER

T HE single-phase motor finds a place in railway work because by its use a high voltage power distribution and current collection becomes possible. The advantage of the single-phase railway system over other railway systems lies in the flexibility of power distribution and control rather than in the motor itself. The motor is, however, an important element of the system, as by its use standard alternating-current distributing systems may be used without any conversion by rotating machinery, thus furnishing the cheapest electrical power distribution known. The Westinghouse series commutator-type railway motor used on single-phase roads is essentially a direct-current railway motor modified in such a way as to permit its operation on alternating current. It should be borne in mind that all changes made in adapting the motor for alternating current also improve its operation as a direct-current motor. The motor losses due to alternating-current are always greater than those due to direct current, the result being inferior performance on alternating current.

With a full realization of these facts, the alternating-current motor designer has as his problem the production of the best motor possible under the limitations of the particular conditions, making use of the best available direct-current experience.

The alternating-current motor differs from the direct-current motor principally in that it has: 1—a laminated field structure; 2—an auxiliary or compensating winding on its field, and 3—preventive leads between the armature windings and the commutator.

The laminated structure is evidently necessary in view of the alternating magnetic flux. The modifications result in increased weight, as it is necessary to support the laminations by a cast steel frame, which is of no assistance magnetically, while in the direct-current motors it is used both magnetically and mechanically.

The auxiliary or compensating winding is used primarily to improve the power-factor of the motor. This improvement is brought about by reducing the inductive element of the armature and further by making a smaller air-gap possible. In consequence of the smaller air-gap, a smaller number of turns in the main field coils is required and there is a smaller inductive voltage due to the main field coils. The auxiliary winding is supported on the stationary element in slots in the pole faces and is connected permanently in series with the armature so that the magnetic action produced by it is in exact opposition to that induced by the armature

and thus the armature reaction on the main fields is balanced, and the field becomes stable.

The preventive leads, connecting the armature windings to the commutator bars, are used for the purpose of limiting the "short-circuit" currents that exist in all coils at the instant that the corresponding commutator bars are bridged by the carbon brushes. The leads in this way assist the commutator and also reduce the motor losses. The fact that the introduction of resistance in these armature windings actually reduces the total armature losses is not always recognized. This reduction in losses is due to the fact that the preventive leads have losses which are caused: 1—By the useful current passing from the commuator to the windings. This loss increases as the resistance of the leads increases. 2—By the short-circuit currents induced in the coils by the transformer action of the main field. This second loss decreases as the resistance of the leads increases. It thus becomes evident that there is a particular value of resistance which will give the minimum loss and any change in this value will result in increased loss. The value of the short-circuit loss decreases quite rapidly as the motor increases in speed, even at the same field strength, on account of the inductance of the coil undergoing short-circuit and the decreased time of short-circuit. The principal value of the leads is in starting when the greatest induction exists in the magnetic circuit and when the duration of short-circuit on each individual coil is greatest. It is necessary, therefore, in designing the leads to make them sufficiently large so that they have the necessary thermal capacity to keep the temperature within safe limits. It is quite possible that the motor may be called upon to withstand a locked condition with full accelerating current for a short period of time and the leads must be rugged enough to undergo such treatment without injury.

Carbon brushes act in the same manner as preventive leads, but they are unable to care for inductions as high as it is desirable to use and need the assistance of the preventive leads for satisfactory performance. The value of the induction permissible when reliance is placed in the carbon brushes alone as a means of limiting the short-circuit currents varies with the grade of carbon, but will in general be of such value as to give approximately 4 to 4.5 volts between bars. It is thus evident that for reduced frequencies, the induction can be increased in direct proportion to such reduction.

The use of preventive leads permits a very material increase in the induction per pole and values nearly double those above mentioned, as the limits in motors without preventive leads, are per-

fectly safe. It is, of course, understood that an increase in the total magnetic induction is desirable, as this gives a cheaper motor.

The use of commutating or inter-poles, which have been generally used on direct-current motors during recent years, materially assists the alternating-current motor after it has attained any speed. It is, however, of no value in starting and of little use at low speeds. In the alternating-current motor the currents under commutation are made up of two components, one the working current in phase with the main field flux, and the other the short-circuit current, considerably displaced in phase from the working current. The magnetic flux variation in a commutating pole, to be most effective, needs to be nearly in phase with the current being commutated and, therefore, cannot be excited by a series winding. If a shunt winding is employed for the commutating poles a complication in connections results and the "automatic adjustment with load" feature of the series connections is lost.

If the motors are provided with preventive leads of the proper value to care for the starting conditions and due consideration is given, in the general design, to the proportions that affect commutation, there will be no need for the commutating poles.

The experience gained from a study of the operation of a large number of single-phase motors in service indicates quite conclusively that this type of motor is the most satisfactory of any thus far developed. It is practically the same electrically as the motor proposed by Mr. Lamme in his paper read before the A. I. E. E. in 1902, and all developments thus far tend to prove the correctness of his judgment expressed at that time.

The statement is sometimes made that the alternating-current motor is not capable of giving as great an accelerating rate as is the direct. As the acceleration depends directly upon motor torque, gear ratio, wheel size and car weights, the matter resolves itself into a consideration of motor torques for overload, as the other factors can all be considered without taking the motor into account. Such a statement then implies that the motors are not capable of standing heavy overload currents during the acceleration period.

That such is not the case is being well demonstrated by the motors on the New York, New Haven & Hartford Railroad Company's locomotives. The motors are frequently called upon to exert twice their hour rating torque in starting, which is more than is expected of most large direct-current motors of similar size.

The St. Clair Tunnel Company's locomotives are equally successful with their large accelerating currents and the large currents used have in no way affected the preventive leads.

METER AND RELAY CONNECTIONS (Cont.)

METERS ADAPTED TO SPECIAL USES

HAROLD W. BROWN

T HE connections discussed in the preceding articles of this
series have been for the purpose of making the measure-
ments for which the various meters were originally intended,
—i. e., voltmeters were to measure e.m.f., ammeters to measure cur-
rent, and wattmeters to measure power, and the capacity of each
meter, together with suitable transformers, was usually that for
which they were originally intended. The present article deals with
connections for making special measurements; in some cases these
connections are for changing the capacities ·of the meters, and in
others for making altogether different measurements.

SERIES-PARALLEL CONNECTION

It is sometimes desirable to vary the capacities of meters by
means of a series-parallel connection. Two meters, as A and B, Fig.
1 (a), may be connected to a two-pole—double-throw switch so that
when the switch is in its upper position the two meters are in series,
and when in its lower position they are in parallel. This connection
is suitable for either voltmeters or ammeters. In the case of volt-
meters, with the parallel connection, the full voltage between the
lines is applied to each meter. With the series connection, if the two
voltmeters are of the same resistance (and reactance, in case of al-
ternating-current circuits), one-half the total e.m.f. is indicated by
each meter. If the meters are ammeters, the conditions are re-
versed, i. e., with the series connection each meter carries the total
current, and with the parallel connection the current is divided be-
tween the two meters.

One of the meters, A or B, of Fig. 1(a) may be omitted, and
in such a case suitable resistances should be inserted at R and R^1 to
divide the currents in the two branches in any desired proportion.
This gives the remaining meter two ranges—with the resistances in
series and in parallel; the ratio of the ranges depends on the rela-
tive resistances of R, R^1, and the meter. This arrangement of re-
sistances is suitable for use with either an ammeter or a voltmeter.

A modification of this scheme for switching resistances, suit-
able for use with a voltmeter, is shown in Fig. 1 (b), where two
single-pole—double-throw switches and two equal resistances are
employed. When the right hand switch is down and the left hand

switch open, *A* is in series with *B*. This inserts the highest resist-
ance in the circuit. When the left hand switch is down and the right
hand open, only *A* is in circuit; and when the left hand switch is
down and the right hand up, *A* and *B* are connected in parallel. If
the voltage drop through the meter itself is negligible, compared
with the drop in the external resistances, the three voltages to which
the meter is adapted by means of these resistances, are in the ratio
of 1, 2 and 4.

Fig. 1 (c) shows how two ammeters may be connected in two
circuits, so that either ammeter will measure the current in one or
both of the circuits. Two single-pole—double-throw switches are
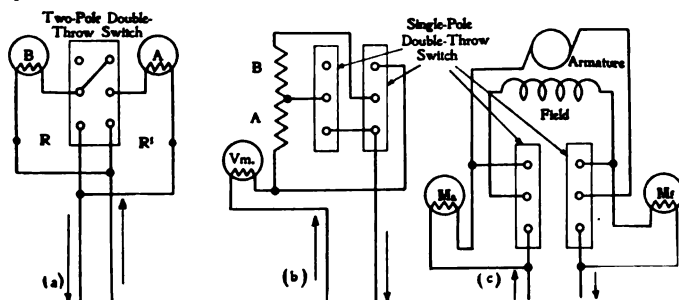employed. When both switches are down, M_a measures one cur-

FIG. 1—DOUBLE-THROW SWITCHES FOR VOLTMETERS, AMMETERS OR RE-
SISTANCES IN SERIES OR PARALLEL

(*a*)—Double-pole switch for two voltmeters or ammeters. The
meters are in parallel when the switch is down, and in series when
it is up.

(*b*)—Two single-pole switches for series and parallel connec-
tions of resistances for use in series with a voltmeter. *A* and *B*
are in series when the right hand switch, only, is down; with the
left hand switch down and the right hand up they are in parallel,
and with only the left hand switch down *A*, alone, is in the circuit.

(*c*)—Two single-pole switches giving simultaneous measure-
ment of two separate currents or the sum of the two on either or
both of the two ammeters.

rent, and M_f the other. When either switch is up, the ammeter on
that side measures the current in both circuits. If both switches are
up, each meter carries the current of both circuits. This last connec-
tion is convenient for comparing the calibration of the two am-
meters. In the diagram the armature and field of a shunt motor are
shown, but such a connection might be similarly used with any
branched or shunted circuits.

Modifications of the connections of Fig. 1 may be extended in-
definitely, with different numbers of switches and resistances, and
with various arrangements of resistances.

METERS FOR TOTALIZING AND AVERAGING

It sometimes occurs, when it is desired to measure total power, that there is no point where series transformers can be placed on the bus-bars or line so as to carry all the current from the switchboard. Such a case is illustrated in Fig. 2. *A* and *B* are sources of the power that flows out on *C* and *D*. The series transformers must be on both *A* and *B*, or on both *C* and *D*, if all the current transmitted is to flow through these transformers. The series transformers on corresponding phases are connected in parallel, and the sum of the currents from the two transformers flows through the wattmeter. The current coils of the wattmeter must have sufficient capacity to carry the currents from the two transformers. With these connections, the wattmeter indicates the total power of the two circuits. Similarly, with any number of circuits, and with corresponding

transformers on each circuit connected in parallel, the wattmeter will indicate the total power on all the circuits.
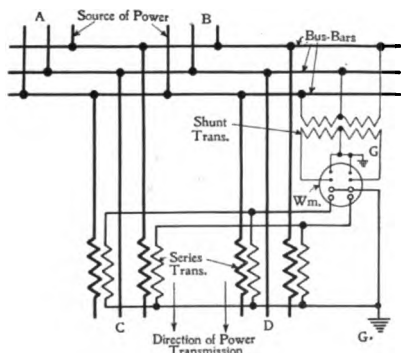
The connections in Fig. 3 are similar to those in Fig. 2, but are for use with an ammeter. If a plug is in one of the receptacles the meter indicates the current flowing in the line designated by the corresponding letter. If plugs are in both of the upper, middle or lower receptacles, the meter measures

FIG. 2—POLYPHASE WATTMETER CONNECTIONS
For "totalizing" power on two or more circuits.

the total current from the corresponding bus-bars. The number of feeders may be increased indefinitely if a row of receptacles is added for each additional circuit, and the capacity of the motor is correspondingly increased.

The connections for a power-factor meter to indicate the power-factor of one or more circuits are shown in Fig. 4. The meter indicates the power-factor of the left or right hand circuit, or the average of both circuits, depending on whether plugs are in the two left or the two right hand receptacles, or in all four receptacles.

Instead of using plugs and receptacles to make connections to the series transformers, the meters in Figs. 3 and 4 may be connected directly to the transformers, as with the wattmeter in Fig. 2. Conversely, the wattmeter may be connected by means of plugs and

receptacles, so as to in-
dicate the power trans-
mitted over all or only
a part of the circuits.

GROUND DETECTORS ON
HIGH AND LOW-TEN-
SION CIRCUITS

Connections for elec-
trostatic ground detec-
tors suitable for circuits
of comparatively high
voltage have been shown
in preceding articles of
this series, but for cir-
cuits of more than
25 000 volts a special
arrangement of con-
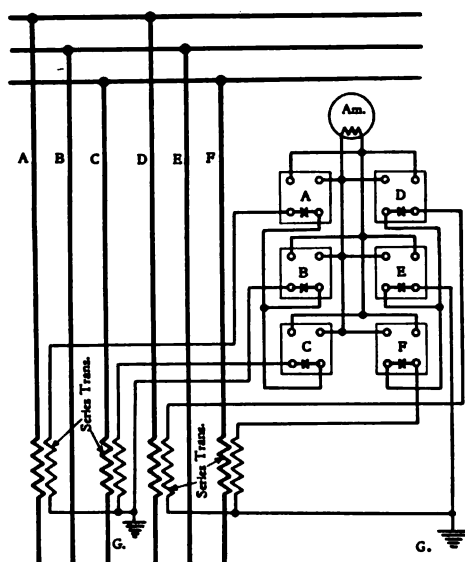densers is employed.
Fig. 5 shows a single-

FIG. 3—AMMETER CONNECTIONS

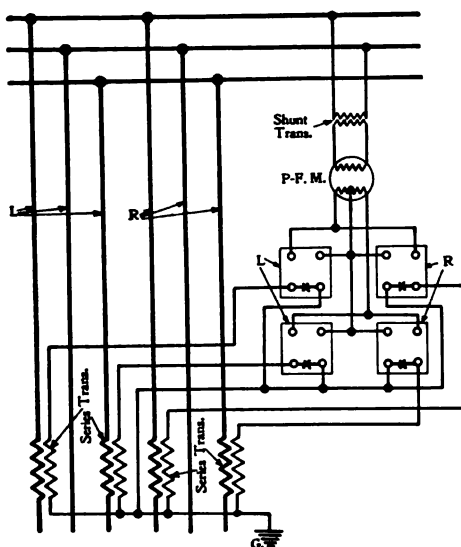For "totalizing" currents in two or more cir-
cuits.

FIG. 4—POWER-FACTOR METER CONNECTIONS.

For measuring the average power-factor of
two or more circuits.

phase ground detector
with condensers for an
88 000 volt circuit. One
condenser on each side
is in parallel with the
ground detector, and
the others are in series.
The e.m.f. on each con-
denser is about 18 000
volts. A larger number
of series condensers is
required for a higher
e.m.f. and a smaller
number for a lower
e.m.f.

Instead of several
series condensers, one
condenser may be used,
if it is insulated for
the required e. m. f.
Fig. 6 (a) shows such

an arrangement, adapted to a 40 000 volt three-phase circuit, requiring two single-phase ground detectors, three high voltage condensers (marked A in the diagram) for connecting in series, and three lower voltage condensers (marked B) for connecting in parallel. Fig. 6 (b) differs from Fig. 6 (a) only in that the two single-phase ground detectors are replaced by a three-phase instrument. The electrostatic capacity of each condenser marked A must be enough smaller than that of each condenser B to prevent an excessive e.m.f. on the ground detectors.

This method of connecting condensers in series and parallel is applicable to electrostatic voltmeters, as well as to ground detectors.

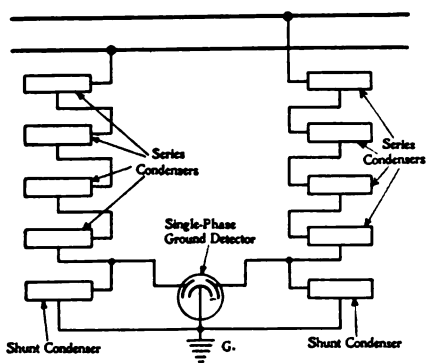Electrostatic ground detectors are not adapted to low-tension circuits, on account of the small torque where the e.m.f. is comparatively low. In such cases some form of electromagnetic instrument may be used. Fig. 7 (a) shows a differential voltmeter (already referred to for use in connection with synchronizing) connected to a single-phase circuit. The arrangement for each phase of a two-phase circuit is identical with that for single-phase. Fig. 7 (b) shows three meters of the same type as in Fig. 7 (a) on a three-phase circuit. If any one of these meters is omitted, the other two will show which line is grounded. The third meter serves as a check on the other two where especially accurate measurements are required. Fig. 7 (c) shows a single meter with an 8-point voltmeter receptacle for connecting to any two of the lines of a three-phase circuit. With each of these arrangements the meter is connected to two lines and shows a deflection when the e.m.f.'s from these two lines to ground are unequal. It is thus possible to determine which line is grounded, for the pointer deflects to the left when the e.m.f. to ground is low on the line connecting to the upper terminal, and to the right when the e.m.f. to ground is low on the line connecting to the lower terminal; the indications of these meters are similar to those of electrostatic ground detectors.

FIG. 5—STATIC GROUND DETECTOR
Connections for single-phase instrument on 88 000 volt circuit.

WATTMETERS FOR MEASURING WATTLESS VOLT-AMPERES.

By far the simplest and usually the most satisfactory method of determining unnecessary line loss due to low power-factor is by means of a power-factor meter. Another method is to measure both the true watts and the wattless volt-amperes, i. e., the product of volts multiplied by amperes in quadrature with the e.m.f. Both of
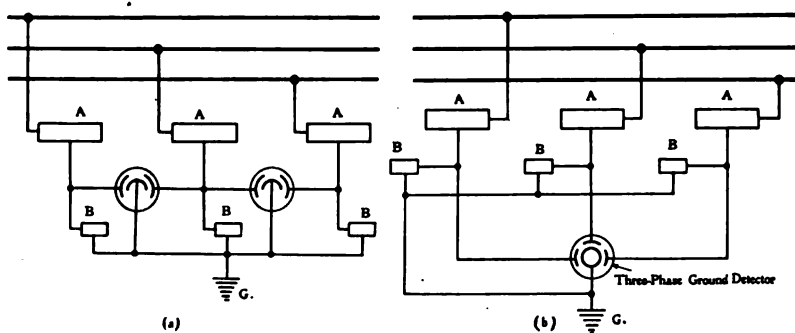

(a)   (b)

FIG. 6—STATIC GROUND DETECTOR

(*a*)—Connections for two single-phase instruments on a 40 000 volt, three-phase circuit.

(*b*)—Corresponding connections for a three-phase instrument.

these measurements can be made by the same wattmeter, or one wattmeter may be provided to indicate true watts, and another to indicate wattless volt-amperes.

In Fig. 8, wattmeter *C* is connected to a two-phase circuit in

(a)   (b)   (c)
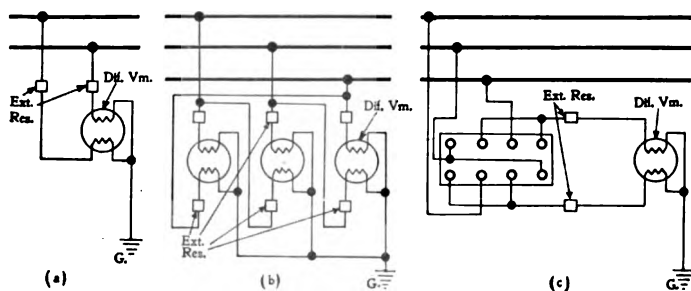
FIG. 7—DIFFERENTIAL VOLTMETERS USED AS GROUND DETECTOR

(*a*)—Connections for single meter on a single-phase circuit.

(*b*)—Connections for three meters on a three-phase circuit.

(*c*)—Single meter on three-phase circuit using eight-point voltmeter receptacle.

the ordinary manner, to indicate true watts, and wattmeter *D* to indicate wattless volt-amperes. The latter meter has its left hand voltage circuit connected to phase *A*, and the corresponding current

circuit to phase *B*. The right hand voltage circuit is connected to phase *B*, and the current circuit to phase *A*. The direction of current in *one* of the e.m.f. circuits should be opposed to the direction in the corresponding current circuit.* For example, in the diagram the direction of current on the right hand side of the meter may be downward (*3* to *4*) in the voltage coil and upward (i. e., opposed) in the current coil, the directions of current in both left hand coils being upward. If it is found that, with these connections, the pointer has a negative deflection the directions of current in both e.m.f. circuits of the wattmeter should be reversed so that the currents on the left are opposed, and those on the right are in the same direction. The lower line from the shunt transformers will then connect to *1*, the middle to *2* and *3*, and the upper to *4*. The direction of deflection (on either a two or three-phase circuit) depends on the order in which the phases follow each other, and on whether the current is lagging or leading.
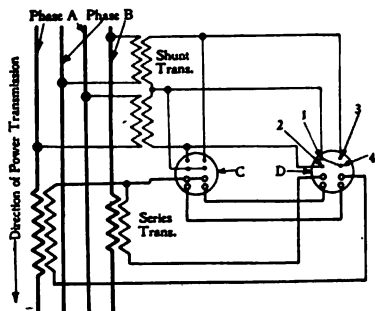
In Fig. 9 a single wattmeter is used, with connections through a four-pole — double-throw switch to the shunt transformers. When the switch is thrown toward *C*, the meter indicates true watts, and when toward *D*, the wattless volt-amperes. If the pointer deflects in the negative direction the connections to terminals *1* and *2*, should be interchanged; also

FIG. 8—TWO POLYPHASE WATTMETERS ON A TWO-PHASE CIRCUIT
C indicates true watts.
D indicates wattless volt-amperes.

connections to *3* and *4* should be interchanged. Either Fig. 8 or Fig. 9 may be arranged with ammeter receptacles; so that, when it is so desired, the current from only one transformer will flow through the wattmeter. The true watts and the wattless volt-amperes may then be measured on the two phases separately, or on both phases at the same time.

Figs. 10 and 11 (a) illustrate connections to three-phase circuits, similar to those mentioned above for two-phase. If the pointer deflects in the negative direction, connections to the four-pole switch should be changed as in Figs. 8 and 9; i. e., connections *1* and *2* should be interchanged, and likewise *3* and *4*.

*See reference to conventions regarding directions of currents, in the JOURNAL for May, 1908, Vol. V., p. 260.

In all of these diagrams, by changing the phase of each e.m.f. two-phase circuit by interchanging the phases. It is done on a three-phase circuit by connecting the e.m.f. circuit from the outer end of one transformer to the middle of the other. This is illustrated in the vector diagram in Fig. 11 (b). In measuring true watts, the e.m.f. on the left hand side of the meter is represented by *AB*; that on the right hand side is represented by *CB*. When the meter is to indicate the wattless volt-amperes the e.m.f. on the left hand side is represented by *CN*, and that on the right by *AM*; *CN* and *AM* are shorter than *AB* and *CB*, illustrating the fact that although the phase relation is right, the e.m.f. is too small for an indication of wattless volt-amperes, if the meter is calibrated to indicate true
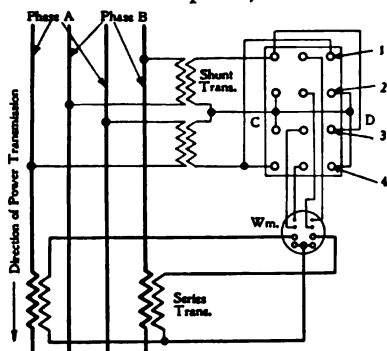

FIG. 9—CONNECTIONS CORRESPONDING TO THOSE OF FIG. 8 FOR MEASURING TRUE POWER AND WATTLESS VOLT-AMPERES, USING A SINGLE POLYPHASE WATT-METER AND A TWO-POLE DOUBLE-THROW SWITCH
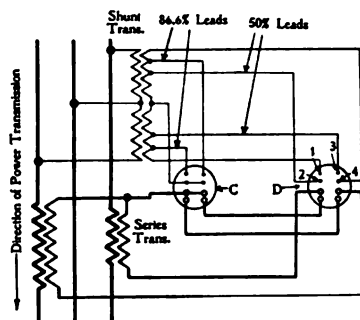*C*—True watts.
D—Wattless volt-amperes.

FIG. 10—CONNECTIONS FOR THREE-PHASE CIRCUIT CORRESPONDING TO THOSE OF FIG. 8, FOR MEASURING TRUE POWER AND WATTLESS VOLT-AMPERES WITH TWO POLY-PHASE WATTMETERS

watts. On this account the shunt transformer leads are brought out at 100 percent of the secondary windings for the wattless connections, and at 86.6 percent for the true watts. Where separate meters are used, as in Fig. 10, to indicate true watts and wattless volt-amperes, this discrepancy could be corrected by a difference in the calibration of the two meters, and in Fig. 11 (a) it could be corrected by providing a double scale on the wattmeter—one to indicate the true watts and the other wattless volt-amperes. In either case the leads that are shown connected to the 86.6 percent points would connect to the adjacent 100 per cent points (thus saving the necessity of bringing out the 86.6 percent tap on the transformer).

A single-phase wattmeter arranged for plugging into any phase of a three-phase circuit, for measuring either true watts or wattless

volt-amperes is shown in Fig. 12. When the voltmeter plug is in one of the lower positions and the ammeter plug is in the corresponding ammeter receptacle the wattmeter indicates true watts on one phase. With the voltmeter plug in the corresponding upper position and the ammeter plug unchanged, the meter indicates wattless volt-amperes on the same phase. The leads to the upper terminals of the voltmeter receptacles connect to 57.7 percent taps on the shunt transformers. This makes the e.m.f. on the wattmeter the same, when the plug is in an upper as when in a lower position.

SPEED INDICATORS

A direct-current voltmeter may be connected to a magneto generator and used as a speed indicator, since the e.m.f. of the mag-
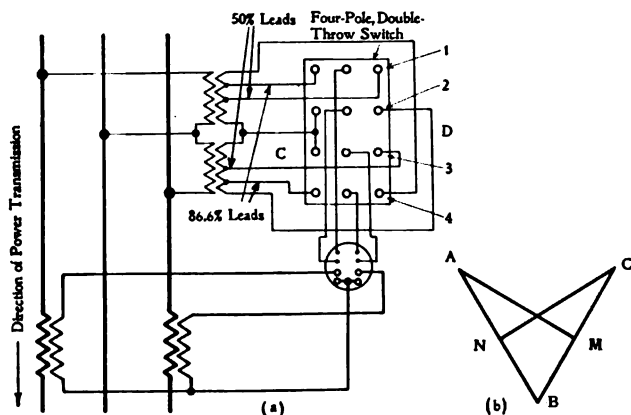
FIG. 11—THREE-PHASE CONNECTIONS FOR MEASURING TRUE POWER AND WATTLESS VOLT-AMPERES BY MEANS OF A SINGLE POLY-PHASE METER AND A FOUR-POLE, DOUBLE-THROW SWITCH

The vector diagram (*b*) represents the corresponding phase relations of the voltages with the switch thrown toward *C* for measuring true watts and toward *D* for wattless volt-amperes.

neto generator is proportional to its speed. A belt running on the pulley or shaft the speed of which is to be measured, drives the magneto. The voltmeter is calibrated to indicate directly the speed that is to be measured. When the speed indicator is to be used on a car or locomotive the scale is usually in miles per hour; but for stationary machinery it is in revolutions per minute.

The speed of alternating current generators is sometimes measured by means of a frequency meter. In this case, the meter is usually provided with two scales, one indicating revolutions per

minute, and the other the percentage above or below normal speed.

SYNCHRONIZING CIRCUITS OF UNLIKE PHASES

The ordinary connections for synchronizing have already been described in a previous article.* In cases where two circuits of a different number of phases are to be synchronized, the connections are the same as for ordinary synchronizing, but the shunt transformers of the two circuits must be connected between lines having the same phase relations. Where one is a two-phase circuit and the other a three-phase and they are connected by the ordinary two-phase—three-phase power transformers, one of these transformers,
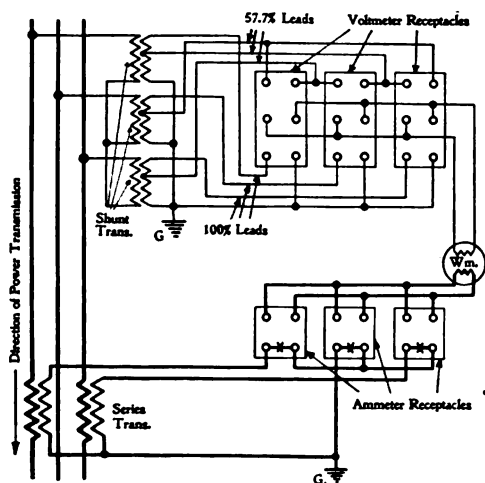

FIG. 12—CONNECTIONS FOR MEASURING TRUE POWER AND WATTLESS VOLT-AMPERES ON ANY PHASE OF A THREE-PHASE CIRCUIT

A single-phase wattmeter, three ammeter receptacles and three six-point voltmeter receptacles are required.

A in Fig. 13, is connected on one side between two of the three-phase line (F and G) and on the other side across phase A of the two-phase circuit. The shunt transformers that are used for synchronizing should be connected, one between F and G of the three-phase circuit, and the other across phase A of the two-phase circuit.

The connections for synchronizing between a three and a six-phase circuit are shown in Figs. 14 (a) and 14 (b).

In Fig. 14 (a) the six-phase circuit is double-delta connected and in Fig. 14 (b) it is diametrically connected. In each case one of the shunt transformers connects to the three-phase side of a power transformer and the other shunt transformer connects to the six-phase side of the same power transformer.

In each of these diagrams showing synchronizing connections, only the synchroscope and two shunt transformers are shown. Other synchronizing apparatus is omitted here for simplicity, since the purpose of these diagrams is only to show the phases to which connec-

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*See article on "Synchronizing" in the JOURNAL for September, 1908, Vol. V., p. 530.

tions are to be made. All the diagrams referred to in the article
on synchronizing ordinary circuits may also be used in connection
with synchronizing two circuits of different numbers of phases.

GENERAL APPLICATION OF METER CONNECTIONS

The meters represented in the present and foregoing articles
have been almost exclusively round type, switchboard, indicating
meters. No difficulty should be experienced in applying these dia-
grams to other types of meters, except possibly in the case of poly-
phase wattmeters and polyphase power-factor meters.

Polyphase Wattmeters.—The diagrams may be applied to other
types of indicating wattmeters than those represented, also to inte-
grating and graphic recording meters. In making such application,
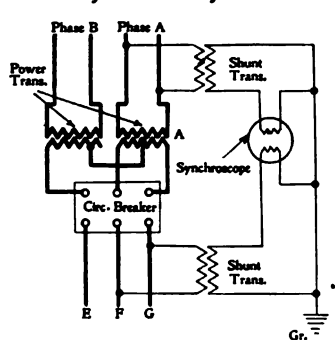it is only necessary to determine what must be the relative directions

FIG. 13—SINGLE-PHASE SYNCHRO-
SCOPE

Connections for synchronizing
between a two-phase and a
three-phase circuit.

of currents (to produce a positive de-
flection of the pointer) in the e.m.f.
and current circuits of the same phase.
Fig. 15 (a) shows a round type
switchboard instrument, with the ter-
minals lettered *a* to *h*. The voltage
circuits are *a-b* and *e-f*, and the cur-
rent circuits are *c-d* and *g-h*. If the
current in the left hand voltage cir-
cuit flows in at *a* and out at *b*, and
that in the corresponding current cir-
cuit flows in at *c* and out at *d*
a positive deflection is produced.
Similarly on the right hand side if
the current in the voltage circuit
flows in the same direction as in the corresponding current circuit a
positive deflection is produced. This meter may be replaced by any
other kind of wattmeter, if the connections are made to terminals
corresponding to those just mentioned. For example, Fig. 15 (b)
represents a portable polyphase wattmeter. When it is known that
a positive deflection is produced by a current in the voltage circuit
from *a* to *b,* and in the current circuit from *c* to *d*, any connections
to such a meter as is shown in Fig. 15 (a) may be applied to corre-
sponding terminals in Fig. 15 (b). In case of an unfamiliar meter
it is a simple matter to find by trial what order of connections gives
a positive deflection, and to letter the various terminals accordingly.
Fig. 15 (c) represents two single-phase portable wattmeters with
lettering similar to the foregoing. If these meters are used on a

three-phase circuit whose power-factor is less than 50 percent, one of them will have a negative deflection. The voltage connections of that meter must then be reversed, and the difference instead of the sum of the two readings should be taken for the power trans-mitted by the entire circuit.
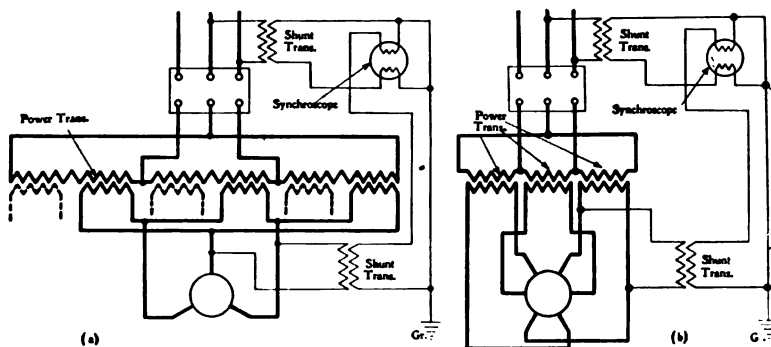
FIG. 14—SINGLE-PHASE SYNCHROSCOPE FOR SYNCHRONIZING BETWEEN A THREE-PHASE AND A SIX-PHASE CIRCUIT

(*a*)—Double-delta-connected.   (*b*)—Diametrically-connected.

Polyphase Power-Factor Meters.—The polyphase power-factor meters represented in the diagrams have two e.m.f. terminals and three current terminals. These meters may be replaced by other polyphase power-factor meters having similar arrangements of windings. For example, Fig. 16 (a) shows a polyphase round type switchboard power-factor meter, such as has been shown in the
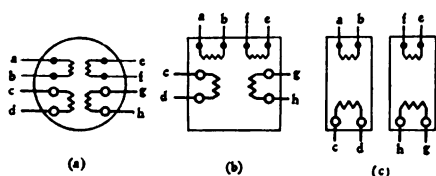
FIG. 15—EQUIVALENT WATTMETER CONNEC-TIONS

(*a*)—Round type polyphase switchboard indicating wattmeter.
(*b*)—Portable polyphase wattmeter.
(*c*)—Two portable single-phase watt-meters.
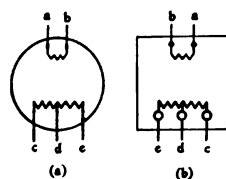
FIG. 16 — POLYPHASE POWER - FACTOR METERS — EQUIVA-LENT CONNECTIONS

(*a*) — Switchboard round type.
(*b*)—Portable type

preceding diagrams. Rear view connections are represented. Fig. 16 (b) shows a portable polyphase power-factor meter, as viewed from the front. The terminals lettered *a* to *e* should have similar connections in the two meters. It will be seen that the order

of portable meter connections from left to right is the same as that of the switchboard meter from right to left, due to the fact that one is a front and the other a rear view.

Transformers.—In most of the diagrams, meters are connected to the circuit through shunt and series transformers. Shunt transformers are necessary on circuits whose e.m.f. is too high for the meters; series transformers are necessary where the current to be measured is too large for the current capacities of the meters, and as well where the line e.m.f. is dangerously high. In the latter case a series transformer with a 1 to 1 ratio insulates the meter circuit from the main line, without affecting the indications of the meter.
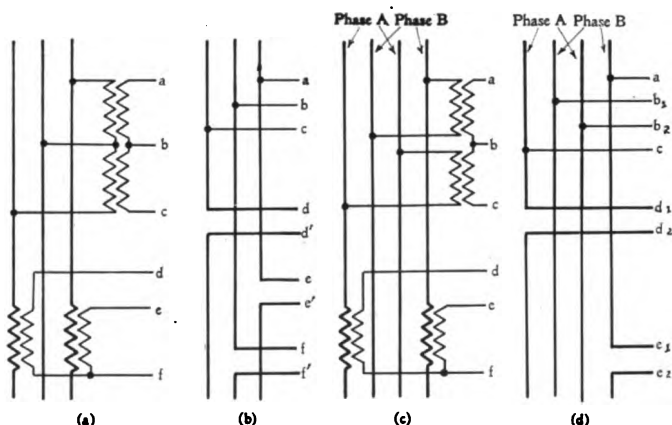

FIG. 17—EQUIVALENT CONNECTIONS WITH AND WITHOUT SHUNT AND
SERIES TRANSFORMERS

(*a*)—Three-phase connections using transformers.
(*b*)—Corresponding connections omitting transformers.
(*c*)—Two-phase connections using transformers.
(*d*)—Corresponding connections omitting transformers.

In cases where shunt or series transformers are not required, the primary circuit connects directly to the meters, as illustrated in Fig. 17 (b) for a three-phase, and Fig. 17 (d) for a two-phase circuit. The series connections are not as simple in Fig. 17 (b), where the transformers are omitted, as in (a), where they are used, because two leads are required for each phase (or, in some cases, to two of the three phases), if connections are made to the primary circuit. The two-phase circuit without transformers, Fig. 17 (d), requires one more shunt, and one more series connection than with transformers, as in (c). On account of the extra connections where transformers are omitted it is sometimes necessary or advisable to use transformers where they would not otherwise be required.

EXPERIENCE ON THE ROAD

TRANSFORMER TROUBLES

J. N. C. HOLROYDE

A TRANSFORMER was supplied to a lighting company which had been accustomed to using the old-fashioned dry type of transformer, in which the induction on normal voltage was very much lower than that which can be used with transformers built of the newest kind of sheet steel.

These people were in the habit of testing their transformers with double voltage across the windings before placing them in service. When the new transformer was tested in this manner a fairly substantial fuse was immediately blown, owing to the exceedingly high magnetizing current which the transformer took, due to the fact that the induction of the iron at double voltage was in the neighborhood of 20 000 lines per sq. cm. The iron in the core of the old transformers they were accustomed to, which would normally have an induction of from 5 000 to 7 000 lines per sq. cm. would not be nearly saturated with double voltage applied. The customer immediately made a complaint that the transformer had broken down on test, but when the matter was investigated and a sufficiently large fuse was inserted, the test passed satisfactorily and no fault whatever was found with the transformer.

Over-potential tests are much better made in the test room, since it is usually quite easy to obtain a considerably higher periodicity than that at which the transformers normally work, and if the periodicity is increased sufficiently, it is quite possible to make the over-potential tests at two or three times the normal voltage without excessive magnetizing current.

CARELESS HANDLING

A large transformer of the circular core type, in service at a large cotton mill, suddenly grounded to the transformer case close to the bottom, When the cause of this trouble was investigated and the transformer was taken out of its case, it was found that it had been very hurriedly installed and no care had been taken to see that it was fixed vertically in the case. It had been put in in such a way that the bottom high-tension coil of one of the outside phases pressed against the side of the case, the marks of the corrugations being very clearly seen on the insulation of the coil.

For some time the transformer had continued to work in this

manner, but eventuality the strain proved too much for the damaged insulation and the coil grounded with the result mentioned above. The trouble was due entirely to the carelessness of those who installed the transformer.

PARALLEL OPERATION

Complaint was made that two transformers supplying power to a mill, and also a certain amount of lighting load, were not sharing their load equally. The engineer in charge of the substation said that the transformers behaved in a very serious manner, and that in the early morning, on starting up the mill, one bank of transformers appeared to be taking about 25 percent more load than the other, but at 7:30 in the morning and from then until about 3:30 in the afternoon, (i. e., when the lighting load was off), they shared

FIG. I
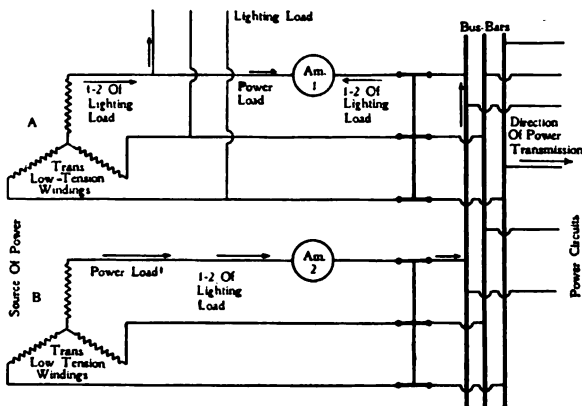
the load equally; when the lighting load was again thrown on, they refused to share the load equally. Investigation showed that this was not due to the transformers, but to the method of making connections. The transformers were connected to a switchboard, on the low-tension side, and each bank fed through its own ammeter to the power circuits. The lighting circuit, however, was connected between one of the banks of transformers and the switchboard, so that any current taken on the lighting circuit was supplied half by one set of transformers and half by the other, but only one-half was measured on the ammeters, and this half passed through both ammeters in such a way that it increased the reading on one and decreased it on the other. The result was that, whenever the lighting load was on, the two sets of transformers apparently were not shar-

ing the load equally, but as soon as the lighting load came off there was no difference whatever in the reading of the ammeters. The diagram, Fig. 1, will make this clear.

IGNORANCE

The ignorance and lack of experience of men employed to handle electrical apparatus is often responsible for both real and imaginary defects therein. In one case a firm operating a large mill, in which they had installed their own generating plant consisting of a steam turbine and an alternator, received a three-phase transformer from the manufacturers and proceeded to dry it out before placing it in service. The transformer was short-circuited on the low-tension side and the high-tension winding was connected directly to the alternator terminals. The turbine was then run at slow speed and the voltage adjusted until the right amount of current was flowing in the windings of the transformer. An attendant was left to look after the apparatus during the night, and possibly went to sleep.

The generator voltage gradually increased until the current rose to such an amount on the low-tension side of the transformer that the short-circuiting pieces across the terminals fused. This threw all the load off the generator, which immediately speeded up, and when next the attendant looked at his instrument he found that the voltmeter was half way around the scale, and that the turbine was running very much faster than when he last noticed it. He then informed his chief, by telephone, that the transformer had broken down. At the urgent request of the mill owners, the makers of the transformer sent an engineer to investigate the cause of the breakdown. On arrival at their works he was told that nothing could be done that day in regard to getting the transformer out of its case and "would he kindly come again another time." On his next visit he was informed by the engineer that there was a short-circuit on every phase of the transformer, which was star-connected, and when inquiry was made as to how the short-circuits were located it developed that the attendant had been testing between phases with a megohm-meter, and finding no insulation resistance between phases, since the windings of the three phases were connected together at the neutral or star point, he immediately assumed that this was due to short-circuits on the windings of the transformer. The transformer was then tested at full voltage, out of the oil as it was, and no fault whatever was discovered, the entire trouble being due to the ignorance of those handling the apparatus.

AN APPARATUS FOR TESTING INSTRUMENTS

CHAS. A. HOBEIN

In testing alternating-current switchboard wattmeters or am-
meters it is customary to arrange a lamp bank or suitable current
transformer in order to obtain the desired variations in load. The
following is a description of a simple and light device which will
vary the current through any range desired.

On most switchboards 110 volt alternating current may be ob-
tained either from the lighting circuit or from the secondary circuit
of potential transformers used to operate voltmeters or wattmeters.
A small transformer with 110 volt primary and two or four volt
secondary is required. As most instruments
are now wound with five ampere current coils
the transformer needs a capacity of only 20
watts in order to give maximum load on a
wattmeter, or maximum scale reading on an

FIG. I
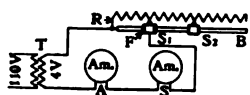
ammeter. In order to vary the current it is necessary to have a re-
sistance. This can be made by winding some iron wire on a cylin-
drical piece of slate or wood covered with asbestos. By connecting
the resistance in the circuit as shown in Fig. 1 the flow of current
can be regulated as desired.

In Fig. 1, T is the 20 watt transformer, S a standard ammeter,
and A the ammeter to be tested. R is the resistance, B is a rod of
copper or brass supporting the slides S_1 and S_2. S_1 is insulated from
B by means of a bushing F, while S_2 is in contact with B. It will be
seen that large variations in current can be obtained by moving slide
S_1, while small variations can be obtained by moving S_2. This ap-
paratus is portable. The amount of current desired can be quickly
adjusted.

THE JOURNAL QUESTION BOX

249—ARTIFICIAL LOADING OF ALTERNATOR—Please give details and description of method of artificial loading of a 350 kw, three-phase generator for purpose of testing. H. P. W.

By reference to the Five-Year Topical Index of the JOURNAL various articles relating to this subject will be found. Note, for example, as follows: "Artificial Loading of Large High Voltage Generators," N. J. Wilson, Nov. '07, p. 611. "Water Rheostat for Treating 2200 Volt Alternator," W. S. Durand, Nov. '08, p. 667. "Test at 80 per cent. Power-Factor," T. Frazer, Jan. '08, p. 51. "High-Tension Water Rheostat," N. C. Olin, April, '08, p. 231.

250—CROSS-CONNECTIONS ON SINGLE-PHASE MOTOR ARMATURE—What is the purpose of the cross-connections on the armatures of single-phase railway motors? H. P.

These cross-connections serve the same purpose as in direct-current generators and motors, viz.: to prevent an unbalanced condition in the armature due to unequal air-gaps at the respective poles. This is explained in No. 54 in the JOURNAL for May, 1908, and subsequently commented upon in No. 161 in the November issue. C. R.

251—CREEPING OF INDUCTION WATTMETER—In examining a certain high-torque integrating watt-meter for use on a 110-volt, 60-cycle, single-phase circuit it was observed that with no load on the circuit to which it was connected and no current flowing in the series coils of the meter, it still continued to operate slowly. Please give an explanation of this and suggest a remedy. S. S. V.

This action is what is known as "creeping" in a meter. The cause

and means of compensating for the action is given in an article on "Integrating Wattmeters," by Mr. H. Miller, in the JOURNAL for October, 1907, p. 595. Slight inaccuracy from this cause may be corrected by an adjustment provided for this purpose in the various commercial forms of instruments. A very marked action of this kind is probably due to a short-circuit in the series coils of the instrument, or otherwise to the displacement of a part of the iron of the magnetic circuit or such pieces as brass clamps or loose screws. If the nature of the trouble is such that it cannot be corrected by means of the ordinary adjustment provided for this purpose, and is not due to one of the suggested difficulties it should receive the attention of the manufacturers. W. B.

252—SHOP TESTS FOR RAILWAY MOTORS—In order to make a complete set of tests on some 35 hp railway motors, what tests should be made and how should they be conducted? M. E. S.

This subject is treated in the following articles which have appeared in the JOURNAL:—"Railway Motor Tests," by R. E. Workman, Oct., '04, Vol. I, p. 551; "Loading Back Large Direct-Current Railway Motors," by C. J. Fay, Vol. III, p. 525, Sept., '06, also, an editorial, "Testing Railway Motors," Wm. Cooper, Sept. '06.

253—BRAKING ACTION OF MOTORS IN PARALLEL—We have several five-ton electric locomotives, each equipped with two 15 hp 220-volt series motors, permanently connected in parallel. When the controller is turned to the "off" position and the locomotive is coasting at a fair speed, it has repeatedly been observed that if the reversing handle is thrown over, the operating handle not being moved,

the locomotive is quickly brought to a standstill in about the same manner as though the brakes were applied with some force and then released just before stopping. It is evident from the fact that the operating handle is not used that the motors did not receive line current, and from the diagram of connections it would appear that both motor circuits are open.   T. S. W.

With the controller handle set as stated above, the connection between the two motors is such that the fields and armatures of the two machines are all in series but disconnected from the line. Both machines pick up as generators. The residual field magnetisms of the two motors are rarely exactly the same, therefore, one of the machines generates a higher voltage, overpowering the other machine and running it as a motor. The conditions are then virtually those of a dynamic braking system, the braking power being sufficient to check the speed of the locomotive. As the braking effect is proportional to the speed, it is evident that when the locomotives come nearly to a standstill the braking action is very slight and the effect is apparently that of releasing the brakes.   F. E. W.

254—TEL-HARMONIC GENERATORS—
   What is the construction of the high-frequency generators used in the tel-harmonic system for transmission of music by electricity?   G. H. S.

These generators are constructed for operation at the various speeds corresponding to the number of vibrations of the various musical notes transmitted by the apparatus. They are laminated with special care, and the iron used in their construction possesses especially good magnetic qualities. This is necessary in order to obtain pure quality of tone and also in order that satisfactory operation may be obtained at the high frequencies involved in the operation of the generators corresponding to the tones of higher pitch. A complete and interesting description of this apparatus is given in an article by Mr. A. S. McAllister on "Some Electrical

Features of the Cahill Tel-Harmonic system," in the Electrical World for January 5th, 1907.

255—OIL ON MOTORS—What is the best method for removing oil from the armatures or field coils of motors? Would the insulation be damaged by spraying or forcing gasoline under pressure over and through the affected parts by means of a small pump? R. H.

When the outside coating of varnish on the coils is intact, gasoline or benzine may be used and will remove the oil as satisfactorily as anything of which we know. When the outside varnish is worn away and the coil has been treated with an asphalt compound before being varnished, the gasoline and benzine will dissolve the compound.   R. A. MCC.

256—SELECTION OF PHASES FOR SYNCHRONIZING—Referring to No. 157 in the October, 1908, issue please explain whether it is not possible in phasing out a two-phase synchronous motor to get the lamps crossed in such a way that, although they may all light up and go out at the same time, they will still be connected to the wrong sides of each phase.   B. L.

The statement in the reply to No. 157 is correct, and single-phase or polyphase circuits may be phased out for synchronizing by this means without uncertainty. However, as the lettering of the terminals of a synchronous machine does not follow any standard rule, this cannot be used as a guide in selecting the phases for synchronizing without first phasing out as indicated in No. 157. Considering further the method outlined therein, one set of bus-bars is represented in Fig. 256 (a) by A_1, A_2 and A_3, respectively, the other set being represented by B_1 B_2 and B_3. One lamp is connected between A_1 and B_1, a second between A_2 and B_2, and a third between A_3 and B_3. At a certain instant, the e. m. f. between A_1 and A_2 is the same as that between B_1 and B_2. If, at the same instant, the e. m. f. between A_1 and A_3 is the same as that between B_1 and B_3, it

follows that the three e. m. f.'s on one set of bus-bars will all be equal to the corresponding e. m. f.'s on the other set, and the lamps, of course, will not light; but if A_2 has an e. m. f different from that of B_2, the lamp between A_2 and B_2 will be bright and the others will be dim, carrying a smaller current. An instant later the lamp between A_2 and B_2 will be bright and the others dim, etc. In this case, it should be necessary only to interchange two connections on one set of busses,—for example, interchange A_1 and A_2, and the sequence of phases will be reversed. Inasmuch as there are only two orders in which the phases of a three-phase circuit can follow each other, if it is wrong the first time it must be right the second time. When all the lamps get bright and dark together, the two circuits must
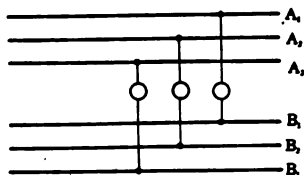

FIG. 256 (a)

have the right phase relations, and the two bus-bars between which any lamp is connected may be connected together. When one of the machines is a synchronous motor it is necessary to drive it, by some mechanical means, at approximately synchronous speed to generate the necessary e. m. f. for phasing out. This method is likewise applicable to two-phase circuits. If the two phases are separate, i. e., are not interconnected, the terminals of the two phases of the machine may be determined by means of a voltmeter; the voltage readings will be equal on the two phases when the proper terminals have been selected. This applies likewise to two-phase, interconnected machines. In this case if the voltmeter be connected across phases, i. e., to one terminal of each phase the voltage reading will be found to be 1.41 times the voltage across one phase. After the proper phases have thus been selected the foregoing method of phasing out for

synchronizing may be applied. The phase relations are not changed by the introduction of step-down transformers, as required in case of high voltage. The directions of currents remain the same as though the circuit were continuous. This is shown in Fig. 3 of article on "Standard Connections" in the JOURNAL for May, 1908, Vol. V., p. 261. See also article on "Synchronizing" in the JOURNAL for Dec., '04, Vol. I., pp. 682-3.   H. W. B.

257—INDUCTANCE FOR MERCURY VAPOR LAMPS—Why is there an inductance coil included in the circuit of two Cooper-Hewitt lamps burning in series, of the type which is started by tipping? What is the effect of an inductance coil used thus on a direct-current circuit?
                                    S. S. V.

When running on current less than about four amperes, and especially when cold, the direct-current mercury vapor lamp, or any mercury vapor apparatus, experiences, at regular intervals, a momentary tendency to drop out. This results probably from the irregularities of the motion of the bright spot on the surface of the negative electrode, (In this connection, see article by Mr. R. P. Jackson in this issue), and is probably also connected with the condition of high resistance to starting, which makes itself evident at the surface of the negative electrode (usually called *negative electrode starting resistance*). There is a tendency toward re-establishing this resistance during the running of the apparatus, but the momentary tendency to go out disappears when larger currents flow or the electrode gets hot. A choke coil in series with one or more lamps operating on the usual currents, viz.: about three and one-half amperes, will resist this tendency to go out, by producing a high voltage impulse lasting until the tendency is past—a very short time. Such a coil is used in all commercial constant potential mercury vapor lamps. This effect occurs in both alternating-current and direct-current lamps and rectifiers, when operating on small currents; this use of a choke coil being entirely independent of the function of keep-

ing a rectifier alive over the zero point of the alternating or pulsating supply current. The same coil may, however, serve both purposes.

P. H. T.

258—WIRING OF BUILDINGS—Can you give a rule for use in figuring the amount of wire and conduit to be used in the wiring of a building for electric lighting, etc.? A familiar method is to measure the building or the plans, as the case may require. A rule using the size of the building or number of outlets would be of great convenience. E. F. B.

We do not know of any general rule which would be of service in such calculations. It is common practice for electrical contractors to keep a record of the costs and material required for the various work handled from month to month, and from this information to derive empirical formulas by which estimates may quickly be made on various classes of new work. As each job has features peculiar to itself, judging the cost is a matter of experience, and it is difficult to obtain a general rule applicable to all cases. Many valuable suggestions may be obtained from various books on electrical wiring, such as that by Cecil P. Poole, Power Publishing Company, New York City, N. Y.

C. B. A.

259—CONDUCTIVITY OF WATER JETS— I have a thesis on the conductivity of water jets on high potential lines. I should like to obtain references to any articles which have been published in the JOURNAL on this subject or any other information of which you know. S. H. S.

The water jet type of lightning arrester is used in various forms by a number of transmission companies in Italy, France and Switzerland. This apparatus is referred to in an article on "Protective Apparatus," by Mr. N. J. Neall, in the JOURNAL for December, 1905, pp. 760-761. It is also referred to in an article on "Italian Power Plants," in the JOURNAL for Februrary, 1909, p. 79. In an article on "Artificial Loading of High Voltage Generators," by Mr. N. J. Wilson, in the JOURNAL for No-

vember, 1907, Volume IV, p. 616, is given a table showing the variation in conductivity of water from various sources, the difference in resistance being due to the presence or absence of various chemical impurities. This is likewise applicable to the conductivity of water jets, and herein lies one of the main difficulties of using water as a means of conducting electrical currents, unless the source of supply is such that the conductivity of the water will remain constant. A characteristic of water such as that obtained from the mountain streams in Switzerland, for example, is its extreme purity and consequent high electrical resistance; hence the success of this type of lightning arrester in these localities. A series of tests was recently conducted by the Pennsylvania Railroad at Altoona, Pa., to determine the risk to the life of firemen handling fire streams, in the event of the water jet coming in contact with a trolley line or high voltage circuit. See "Handling of Line Wires and Fire Streams" in *The Electrical Review and Western Electrician*, November 7th, 1908, p. 690. S. Q. H.

260—SINGLE-PHASE RAILWAY LOAD ON THREE-PHASE GENERATOR— A single-phase railway load is supplied from a sub-station equipped with a motor-generator set. The motor is driven from a direct-current source. The generator is a 6 600-volt, three-phase, star-connected machine. The load is taken from one phase and the switching apparatus is so arranged that, in case of breakdown, the load may be transferred to one of the other phases. Would this be considered good practice, and, if not, what trouble would be likely to occur? S. G. MACD.

The practice of using a three-phase generator and transferring a single-phase load of this character from one phase to another in case of trouble is entirely allowable, and, in fact, is sometimes considered very good practice. On the other hand, the reason for using a single-phase system when there is a direct-current source of power, thereby necessitating a motor-generator set at the

sub-station, is not at all obvious. The only condition under which such an arrangement might be advisable would be in case the railway is of considerable length and the cars operate at only long intervals, thereby rendering the simple high-voltage alternating-current trolley circuit much cheaper. In other words, under these conditions, such a single-phase system might be found to give more satisfactory operation as regards transmission losses and voltage regulation with a minimum expenditure for copper.   F. E. W.

261—PHANTOM GROUND—In a 2300-volt, 60-cycle three-phase power plant the generator is a 200-kw star-wound machine without neutral, there being on the switchboard an indicating voltmeter connected to a 250-watt transformer, having a ratio of 20 to 1. This transformer is so arranged that the voltage between any two phases can be obtained; also so that the primary will be connected between any one phase and ground. When plugged in the latter way, the voltage indicated on any phase is practically 58 percent of the voltage between the two phases. At first I thought this apparent ground might be due to static or leakage effects, and, therefore, connected two 32 c. p. lamps in parallel with the voltmeter. This, however, did not remedy matters. Please explain the cause of this apparent ground. The distribution circuit consists of a 110-volt, three-phase secondary circuit, and a 220-volt primary circuit, each connected in "V."   F. P. R.

This apparent ground may be due either to "static" (i. e. line charging) or leakage effects. The transformer ratio is 20 to 1, and a current of two amperes flows in the secondary; so that only 1/10 ampere flows in the primary from the line to ground. On a well insulated 60-cycle circuit it would seem probable that it is due to line charging, rather than to leakage.   H. W. B.

262—FIELD TRANSFER SWITCH FOR INVERTED ROTARY CONVERTER—In a well-known handbook I

have noticed the following: "When a rotary converter is run inverted (i. e., to convert direct-current into alternating-current), provision must always be made for starting the rotary from the direct-current side. A field transfer switch should be provided for use in starting." "Rotary converters started from the direct-current side require a field transfer switch. These are usually provided with the direct-current panel. A double reading ammeter is usually provided or else other provision is made to prevent damage to the meter by reversal of current." Please explain the use and meaning of the "transfer switch." Why is it used in the field when the rotary converter is started from the direct-current side and not used when it is started from the alternating-current side? What is meant by "starting switch?"   E. W. P. S.

When a rotary converter runs inverted without any other alternators on the same line, its speed is governed by the same laws which govern the speed of an ordinary shunt motor. In starting up such a rotary converter from the direct-current side full field is used, the same as with any direct-current shunt motor. If it is feeding into an alternating-current line on which there are other alternators, it must be synchronized, and will then run as a synchronous machine. However, when feeding into an alternating-current line for which it is the only source of supply, its speed is no longer synchronous, but will vary as the direct-current line voltage varies, and as its own field strength varies. If a heavy lagging current be drawn from such a rotary converter this current has a large demagnetizing effect on the field, and hence the speed of an inverted rotary is apt, under such conditions to reach a dangerous point. Separate excitation of the field must be resorted to in this case, and this is usually done by mounting an exciter on the same shaft. If the rotary tends to speed up, the exciter also speeds up and its electro-motive force is raised, thereby producing an

increase in field current on the rotary itself. A speed limiting device is generally used in addition to the separate exciter. In the diagram, Fig. 262 (a), the rotary converter is shown with its field connected to the
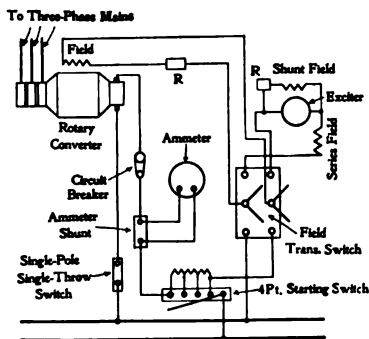

FIG. 262 (a)

main direct-current bus-bars. When the rotary is up to full speed the field transfer switch is thrown in such a manner as to secure field excitation from the exciter. The field transfer switch is so arranged that one side of the switch does not leave the switch jaws until the other side has made contact, thus avoiding any break in the main field of the rotary. The only precaution necessary is to see that the polarity of the exciter connections is correct relative to the main bus-bars, and that its voltage is the same as that of the bus-bars. The starting switch is diagramatically shown and is nothing more than a combined switch and starting resistance. The blade of the switch short-circuits successively the various portions of the starting resistance. This form of switch is described and illustrated in article by Mr. Wm. O. Milton in the JOURNAL for Dec., 1907, Vol. IV., p. 704.   E. S. Z.

263—FLY-WHEEL FOR REDUCING FLUCTUATIONS—Given an interurban trolley line nine miles long, with average grades, curves and schedule speed; three 30-ton cars on line equipped with four 40-hp., 500-volt direct-current motors each, and power to be supplied by a 60 000-volt, 60-mile, 60-cycle

transmission line with 2 500 kw generator capacity; please advise if a fly-wheel on the motor-generator set supplying the direct-current railway load, would absorb the fluctuations satisfactorily so as not to interfere with lighting service from the transmission line, or would storage battery regulation be necessary in such a case?   F. C.

It is assumed from the statement of the question that the lighting load is to be used only on cars and in stations, etc., and not for residence lighting. The requirements of the latter are much more exacting, and an arrangement of motor-generator set and fly-wheel of reasonable size probably would not be sufficient to absorb the fluctuations due to varying railway load, as the latter would appear to be fifty or sixty percent of the total load, and the lighting load about forty percent. Such fluctuations would not be so serious as to be prohibitive in case only railway lighting is required. Calculations for a given case would require complete information regarding the conditions and requirements of the service, and would be a somewhat lengthy and laborious task. The final arrangement decided upon is even then one requiring judgment and experience.   A. K.
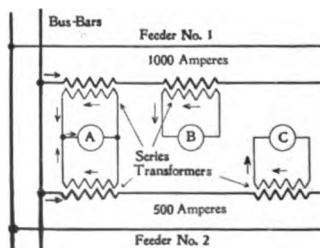
ERRATUM

FIG. 179 (a)—DEC., 1908

In order to correctly indicate instantaneous values, that line of each feeder circuit containing series transformers should be connected to the same bus-bar, as indicated herewith, instead of as shown in the question.

Cost of Motor, Power and Product
In selecting a motor for a definite service or in laying out a general power system for industrial purposes, how important is it to economize in the first cost of the motor and in the amount of power to be used? The reason for installing and operating a motor is usually to produce a better or cheaper product. The first cost of the motor and the cost of the power which drives it are elements in the total cost of production. And yet the cost of the motor and of the power are often in themselves of so little importance that to economize in them may be wasteful and foolish.

As an illustration, it will be assumed, for convenience, that for a typical case the cost of the motor is $25.00 per horse-power, that the annual cost of the power required to drive it is $25.00 per horse-power of its rated capacity and that the cost of power is five percent of the total cost of production, which is, therefore, $500.00 for each horse-power of motor capacity. If the interest, depreciation and repair to the motor be taken at the high figure of 20 percent, then the fixed charges per year will be 20 percent of $25.00, or $5.00 per year. This is one percent of the assumed total cost of production. These figures are assumed in order that the following discussion may have a concrete basis. The cost of a motor per horse-power will, of course, be much greater for small motors and less for large ones. The cost of power per kilowatt-hour varies considerably and the amount of power used per rated horse-power capacity depends upon the load factor. The cost of power is in many manufacturing operations much less than five percent of the total cost of production, although in other cases such as electro-chemical industries, it is much higher. The annual charge of 20 percent on the first cost of the motor is much too high, but it is a convenient figure to use and a lower value would only increase the force of the conclusion which is reached.

First, to what extent is it economical to economize in the amount of power used? The assumed cost of power at five percent

of the total cost of the product allows a considerable increase in the cost of the power, provided even a relatively small saving can be effected in the cost of the other elements. For example, if an increase of 20 percent in the amount and cost of power used enables the output to be increased by only five percent the result is well worth while, for on the above basis there will be an additional cost of 20 percent of $25, or $5.00, for power and a saving of five percent of $500.00, or $25.00, giving a net saving of $20.00. In general the problem is not how to use as little power as possible, but how to apply as much power as can be used effectively. It is the cost of labor and the quantity of output which can be secured from a given factory equipment which are usually the large factors in the cost. In the case above assumed, it would be economical to double the amount of power used if by increasing the output or reducing the labor charge there would be a resulting reduction of more than five percent in the total cost.

Second, to what extent is it economical to economize in purchasing a motor equipment? The annual charge resulting from the first investment in a motor is, in the above assumption, one percent of the total cost of production. The question now arises whether a different motor equipment could cause a reduction in the final cost. Suppose, for example, that the facility for exact speed control would enable the motor speed to be adjusted so that it would operate the machinery which it drives at exactly the maximum speed permissible. The adjustment, which may be different under different conditions and require varying at intervals, may enable the average speed to be increased so that there is an increased output and a reduction in labor cost which in a given case may amount to, say three percent of the total cost of production. This will justify an additional expenditure for the motor equipment up to three percent of the total cost of production, or $15.00 per year, which is three times the annual charge assumed for the first cost of the equipment, which in turn would justify an initial investment of $100.00 instead of $25.00. In other words, when the annual fixed charge for an ordinary motor is $5.00 per year for a production amounting to $500.00 per year, it would be profitable to invest several times as much if an equipment can be secured which will enable the total cost of the production to be reduced by even a relatively small percent. Thus, if through facility for exact speed control, or convenience in making speed adjustments, or if an indicating or automatic device be supplied for determining the speed at which a

motor can be run, or if exact adjustment of speed secures a more uniform or superior product, or if a sturdy and reliable motor secures a continuity of service which prevents uncertainty and delay, or if any other advantages can be gained by purchasing a motor and controlling device which may cost several times that of an ordinary equipment, then the investment would be justified if it will result in a saving of even five or ten percent in the other elements which make up the total cost.

In general, there are few operations or processes which are not capable of improvement in quantity or quality of output by modifications in the method of supplying power. The electric motor has successfully superseded other sources of power not merely because it is usually able to deliver a given amount of power at less cost, but because it results in indirect but very considerable economy in its convenience, cleanliness, facility for increased or exact adjustment of speed, reliability or continuity of service. All these are elements which, directly or indirectly, constitute the real reasons why the motor is so successful. Hence, in the application and use of motors, it is essential to make a careful study of the conditions which have limited the quantity and quality of the output and to determine how these may be best overcome by new methods which may be made possible by the motor. Under ordinary conditions the actual cost of the power used is insignificant, provided a comparatively small percent reduction in the cost of labor can be effected. It is quite astonishing to find that one is justified in paying several times as much for a motor and its control apparatus provided it is even a trifle more effective in performing the work it is to do.

The efficiency of a motor is quite different from effective performance; a gain of one percent in efficiency is a gain in power consumption, on the foregoing supposition, of one percent of $25.00, or 25 cents per rated horse-power per year, while a gain of one percent in reducing the total cost of the product is one percent of $500.00, which is $5.00. Efficiency in power consumption, important in itself, is of trivial consequence compared with effectiveness in performance.   CHAS. F. SCOTT

**The
Motor-
Generator
Fly-Wheel
System**   The actual results otained from the use of an interesting and comparatively recent application of the electric drive to mine hoists are presented in the article on the "Operation of Mine Hoists by Electric Motors", by Mr. C. V. Allen, in this issue of the JOURNAL.   These hoists require rapid acceleration and running, together with ease and accuracy of control.   The steam engine meets these conditions admirably and for many years was the best and only method available.   It is beginning to be superseded by the electric motor in hoisting work as it has been in many other lines.

An electric motor may be applied to a mine hoist and receive its power directly from the line.   When so applied, however, it places large peak loads on the line, and this is objectionable especially with motors of large capacities.   When used in this way close control of speed is not easily obtained.   To overcome these objections, the motor-generator fly-wheel system described by Mr. Allen has been developed.   In this system a motor-generator set is interposed between the hoist motor and the line.   Such a set consists of a motor taking its power from the line and driving a direct-current generator which supplies the necessary power to operate the hoist motor.   On the same shaft with these two machines is mounted a heavy fly-wheel.   By suitable control of the speed of the driving motor, energy is stored up in the fly-wheel at times of light load on the motor.   This energy is given up to the generator at times of heavy load on the hoist motor.   In this way the maximum peak load from the line is reduced and a comparatively uniform amount of power required from the line.   This result is particularly desirable on long transmission lines where such motors are often installed.   The use of direct-current generators and hoist motors makes it possible to use an extremely simple and reliable system of voltage control for speed and direction of rotation.   An interesting feature is the range of variation in performance that can be obtained by merely changing the adjustment of the apparatus.

The results obtained in the El Oro plant indicate how satisfactory such an equipment may become in actual practice.   It appears from the results already obtained that hoist equipments of the character described open up possibilities in the way of more economical production in mining that should excite the attention of mine owners and operators, especially in cases where the cost of steam power is high and water power is available.

W. A. DICK

"To tax water powers for the purpose of provid-
Water Power ing free waterways, from a broad economic stand-
and point, is a policy which, before adoption, should be
National compared carefully with the plan of imposing tolls
Conservation upon all users of inland waterways and using the
proceeds to develop water powers and secure
cheaper power for our manufacturing industries."—This sentence,
from a strong paper on "Electricity and the Conservation of En-
ergy", by Mr. L. B. Stillwell, published in the May, 1909, Proceed-
ings of the American Institute of Electrical Engineers, proposes to
shift by 180 degrees the ordinary attitude toward the use of our
streams.

It is commonly assumed that the use of canals and rivers
for purposes of transportation is in the nature of a public utility in
which all are concerned. The development and maintenance of
public waterways has therefore been regarded as a proper subject
for public taxation. On the other hand, the generation of power
from water falls and systems for its transmission, distribution and
use have been regarded in the nature of private enterprises of little
or no public concern and as suitable objects for taxation.

Mr. Stillwell points out that the annual gross output of our
factories and mills is about \$17 000 000 000, representing approxi-
mately 16 000 000 horse-power installed, while the gross receipts of
our railways is approximately \$2 325 000 000 or about 14 percent
of the value of the manufactured products; that, as the object of
constructing inland waterways is to reduce the cost of transporta-
tion, the suggested taxing of water power developments in order
to construct waterways would impose a tax which would tend to
increase the cost of manufactured products in order to attain an
indefinite advantage in reducing the cost of transportation, which
is only about one-seventh of the amount involved in manufactur-
ing. This proposition is made although the manufacturing costs in
America are much higher than in Europe, while our cost of trans-
poration per ton-mile is materially lower.

The interests of the public in power developments are not gen-
erally understood. Power is not a luxury, but an essential element
in modern life. Its cost enters into the cost of manufactured prod-
ucts and is therefore a factor in the cost of practically every manu-
factured article which we use. The cost of power is often a funda-
mental condition upon which depends the development of a useful
industry or the building up of a community.

The supply of electric power for purposes other than manu-facturing must not be overlooked. The electric lighting of streets and houses, the varied applications of electric current for heating, the growing use of the motor in the house and office and store and small place of business, and the electrical operation of pumps and elevators, street and interurban cars—these applications of electric current in daily life are making the general supply of cheap power a public necessity, and the use of electricity a decade from now will be many times as great if the present rate of increase continues.

Modern civilization has the steam engine as its basis. Our methods of transporation by land and sea, our methods of manu-facture by machinery instead of by hand, our every-day convey-ance by electric cars and elevators, our illumination, ventilation, refrigeration, all these and many more, are based upon the steam engine. The electric system of transmission allows the distant water power to be substituted for the engine and its boiler. It sub-stitutes the water fall for the coal pile.

The first concern in a wise movement for conservation of na-tional resources should be to conserve the diminishing supply of precious coal by utilizing fully the wasting energy of the ever-flow-ing river. Mr. Stillwell shows that the electric power furnished by one of the companies at Niagara Falls last year saved 1 000 000 tons of coal. Will not the general supply of electricity for light and heat and power to the next generation for domestic and manu-facturing and general purposes be almost as essential as the public supply of water for like purposes? Is it not time that power be considered no longer a private commodity, but a public utility? Would not subsidy be wiser than taxation?

<div align="right">CHAS. F. SCOTT</div>

OPERATION OF MINE HOISTS BY ELECTRIC MOTORS

WITH SPECIAL REFERENCE TO THE INSTALLATION OF THE EL ORO MINING & RAILWAY COMPANY, LTD.

C. V. ALLEN

A POWER COMPANY engaged in selling power to various interests concerns itself not alone with the greatest load it can connect to its circuits, but with the nature of that load. A company supplying a strictly lighting load with the usual heavy peak for two or three hours out of the 24 is a poor money maker. It is the motor load which keeps the plant busy the rest of the day that improves the load factor and increases the profits. In a country like Mexico, where about 60 percent of the industry is mining, the power companies find a greater part of their customers
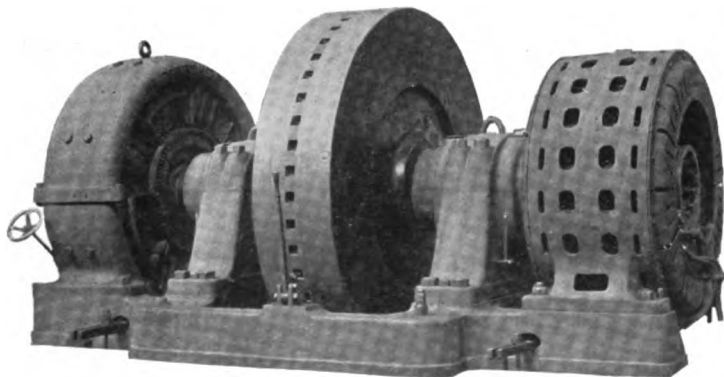

FIG. I—MOTOR-GENERATOR FLY-WHEEL SET
Comprising 350 kw, 250 volt direct-current generator; 350 hp, 3 000 volt alternating-current motor and 40 000 lb. fly-wheel.

among this class, and, as gold and silver are the principal metals mined, the ore is generally milled on the property. This subdivides the power consumed by this class of customers into mining and milling service. The latter is an ideal power user, with practically a constant load almost every hour in the year with the resultant high load factor. With mining, while the pumping, haulage, air compressing, ventilating, etc., is as a rule a steady load, the hoisting load is far from uniform.

Hoisting, with its objectionable peaks at time of acceleration, has long been a disturbing element, especially where the hoists are

large in proportion to the power plant capacity, or where they are located at the end of a long transmission line. Many methods have been devised to try to overcome this peak feature, the most successful and practical of which, where alternating current is the source of supply as is almost invariably the case, is the motor-generator fly-wheel system. While this method is by no means new it is practically so as applied to hoisting in this continent. A description of its application may be of interest, the principal object of this article, however, being to refer to a particular installation, that of the El Oro Mining & Railway Company, Ltd., in Mexico, showing actual results obtained.

FIG. 2—CLOSER VIEW OF SAME FLY-WHEEL SET AS IN FIG I.

Showing fly-wheel and brake attachment.

The El Oro camp is the largest electric power - consuming district in Mexico, there being installed over 30 000 horse-power of electrical apparatus, with a total load consumption of about one-third of that amount at the present time, with a resultant load factor of over 90 percent. Power for this camp is supplied by the M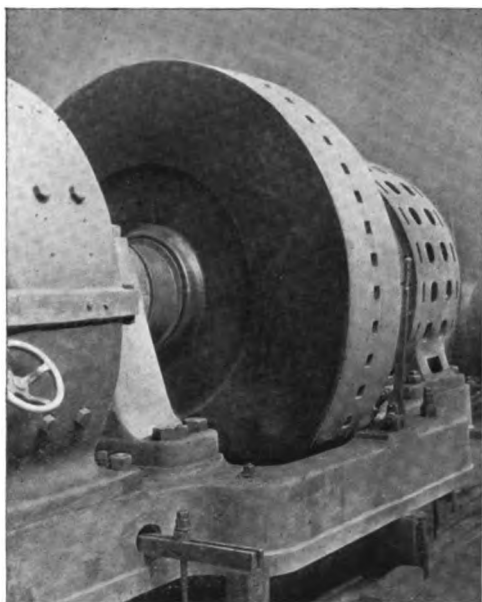exican Light and Power Company. It is located 171 miles from the source of power, there being a total of about 4 000 horse-power in motors installed for hoisting service alone. Of these hoisting outfits there are four motor-generator fly-wheel sets in use, with a fifth under construction. The largest of these five fly-wheel hoisting sets, of 400 horse-power capacity, has been in operation for one and a half years, and is the one considered in this article.

For its own protection, in preventing disturbances on its system, a power company naturally must establish a limit beyond which an ordinary induction hoist motor will not be permitted on

its circuits. For these heavier hoisting conditions, which are getting heavier with time as the shafts become deeper and the hoisting speed consequently increased, the motor-generator fly-wheel system adapts itself admirably. While admitting the comparatively high first cost on account of the number of machines employed, economy and perfect control are compensating features, the former more par-
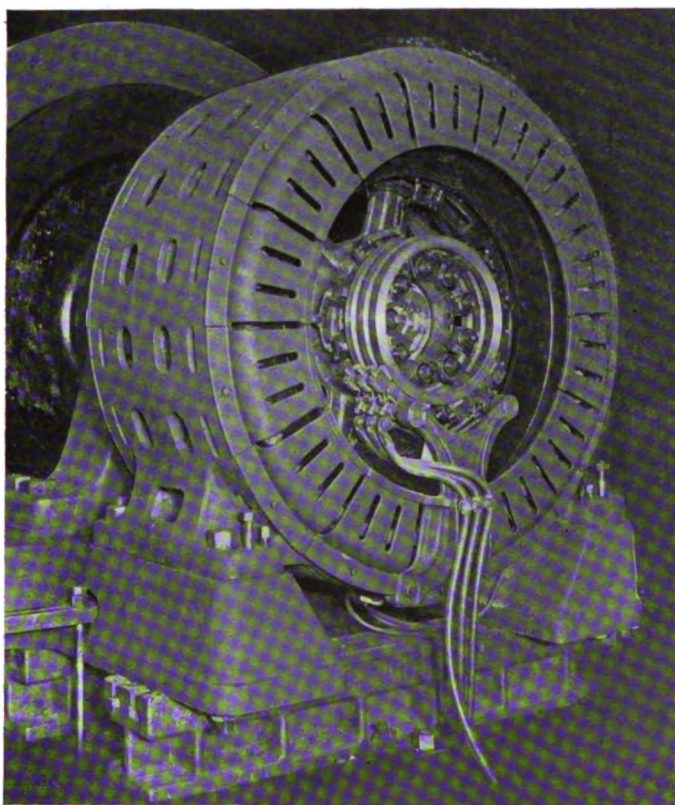
FIG. 3—ALTERNATING-CURRENT END OF MOTOR-GENERATOR FLY-WHEEL SET

ticularly where the operation is quite continuous.

The fly-wheel set installed at the incline shaft of the El Oro Mining & Railroad Company's property, consists of a 350 horse-power, alternating-current, 50 cycle, three-phase, 3 000 volt, induction motor, and a 320 kw, direct-current, 250 volt, interpole generator, with a 40 000 lb. fly-wheel 9 feet in diameter, mounted on a

common shaft between the two machines; the no-load speed of this set being 480 r.p.m. A 17 kw, 125 volt exciter is belted to a pulley on the main shaft of the set at the side of the fly-wheel.

At the shaft where the greatest amount of ore is taken from the mine, which is inclined 62 degrees from the horizontal, there has been in operation for many years a double, flat drum, steam hoist, which has been slightly modified to adapt it to motor drive. In order not to disturb the crank discs and their connection to the former steam cylinders, a new shaft, fitted with bearings and pinions,
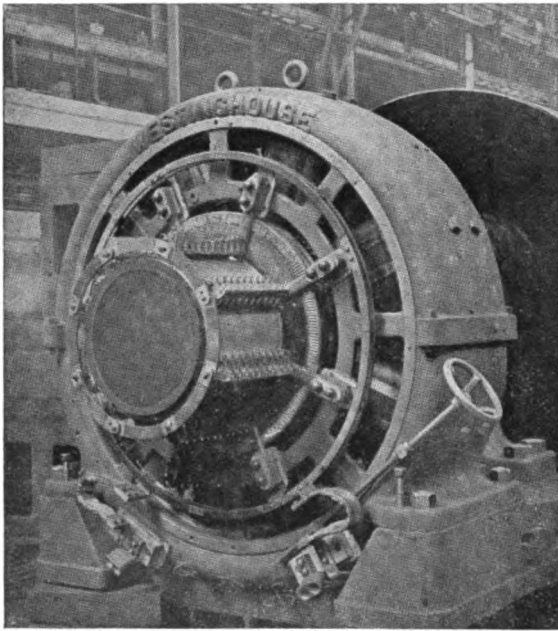

FIG. 4—DIRECT-CURRENT END OF MOTOR-GENERATOR FLY-WHEEL SET

was placed on the back of the hoist, to which was coupled a 400 horse-power, 250 volt, 225 r.p.m., direct-current, shunt wound motor. By thus retaining the steam cylinders and their drive intact, it is possible to use the steam end as an air compressor to act as an auxiliary brake for the hoist, the braking thus being controlled, to a fineness impossible with the usual brake bands, by a small valve on the hoist platform which controls the amount of compression.

While the above method is in use with other hoists, at this

particular incline hoist, steam was employed for a short time in the four auxiliary cylinders used for operating the brake bands and clutches; this work, however, is now being done by hydraulic pressure, the water being taken from an elevated tank located considerably above the hoist. The electric braking feature possible with such a motor-generator fly-wheel set is utilized and is no little economy, as well as furnishing extra safety, in that the hoist motor when coming to rest delivers power back to the set, and thence to the line.

In the operation of this system as a whole, the purpose of employing a motor-generator set is to permit the use of a fly-wheel as a means of providing a storage of energy which can be drawn upon at the time of the acceleration of the hoist load when the most objectionable peaks are encountered. By this arrangement the imput to the alternating-current motor on the set is maintained nearly constant, depending in part upon the size of the fly-wheel. If the fly-wheel is to give up its stored energy at the proper time it is essential that some method be employed to vary the amount of slip in the alternating-current motor which, in the set in question, is accomplished by an automatic arrangement which provides for cutting in and out resistances connected to the secondary of the motor. In this case the slip amounts to about 20 percent. The resistances are of the grid type and the automatic switches used with them are of the multiple control type and divided into three units. These switches are operated by compressed air, the valves being controlled by direct-current magnets.

This exciter is used to excite the fields of both the generator on the set and the hoist motor, there being in the circuit of the motor field a field rheostat for varying the strength of the field. This is located on the hoist platform, thereby enabling the operator to vary the speed of hoisting, but when once set for the proper speed, the rheostat is ordinarily left in this position, unless it is desired to change the speed for special reason. A discharge resistance is also permanently connected across the terminals of the motor field.

In the field circuit of the direct-current generator is connected a controller which is located on the hoist platform and employed for varying the field of the generator from zero to maximum and also for reversing. This gives a fixed strength of field corresponding to a fixed speed with constant armature current in the motor. A resistance is also so connected that the field of the generator is at all times shunted by it, so that if the supply circuit is interrupted

the generator field will discharge through this resistance. In order
to get quick operation in the generator field, as well as for the
purpose of adjustment, an external resistance is also employed, con-
nected between the supply circuit and the controller; this latter re-
sistance being mounted on the switchboard.

The armatures of the hoist motor and the generator are elec-
trically connected together, and the reversal in speed of the hoist
motor is obtained by reversing the field of the generator. When
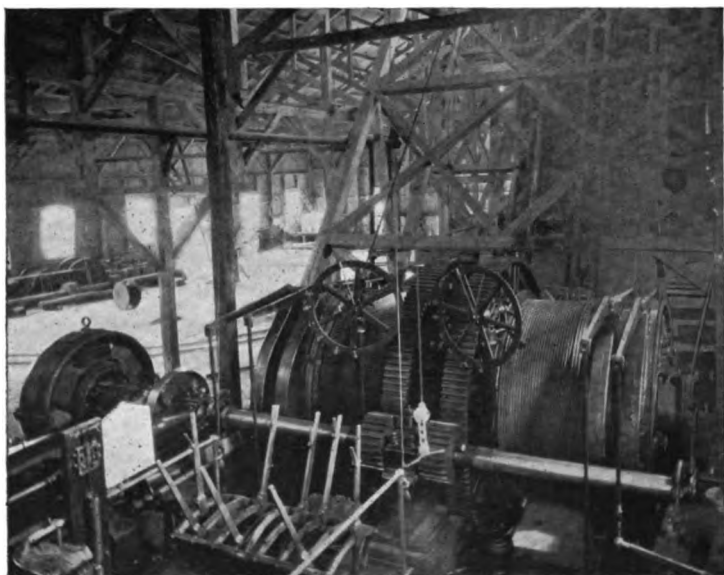the hoist is at rest the controller is in the off position and the gen-

FIG. 5—INCLINE SHAFT HOIST AS AT PRESENT OPERATED
Except motor pinion shaft is at back of hoist instead of front,
as shown.

erator field open, thus giving zero field on it and zero voltage on
its armature, and therefore on the motor armature. In starting a
load the generator field is closed with all resistance in circuit and
this resistance gradually cut out by the operator until the maximum
voltage is obtained; when full voltage, 250 volts, is applied to the
motor terminals.

In the supply circuit between the exciter and the other appara-
tus is located a circuit breaker provided with an overload trip pro-
tecting the exciter from short-circuit or ground. This breaker is
also provided with an underload trip placed in series with the field

of the direct-current motor, so that in case the motor field circuit becomes open at any time the circuit breaker trips, thereby reducing the generator voltage to zero, to prevent the running away of the motor by losing its field.

On the switchboard are located the alternating-current voltmeter, wattmeter, ammeter and circuit breaker connected with the main source of supply. There are two series transformers between the circuit breaker and the motor for operating the tripping coils of the breaker; a third series transformer being connected to a compensator which is used to feed the current relays. These relays vary the amount of resistance in the secondary circuit of the motor
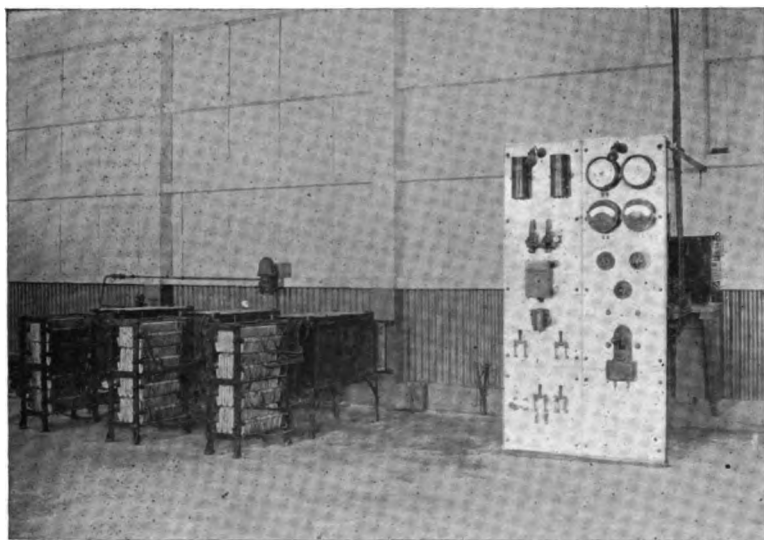

FIG. 6—VIEW OF SWITCHBOARD, RESISTANCES AND ELECTRO-PNEUMATIC SWITCHES

by means of the eighteen electro-pneumatic switches. One of these relays when closed causes the switch to short-circuit the resistance step by step to reduce the slip of the motor, thereby causing the motor to take full current for which the compensator is set. The other relay when closed retains the resistance switches in a closed position after the first relay has closed them. At any time when the current reaches the value for which the compensator is set the first relay is drawn up, opening its circuit and preventing any more resistance switches from closing. If the current continues to increase in value the second relay lifts, opening its circuit and thus causing

the resistance switches to open in the reverse order, thus increasing the slip of the motor.

Across two of the lines connecting the primary of the induction motor to the circuit breaker is located a second shunt transformer which energizes the coil of the line relay. This line relay is closed as long as there is a voltage on the primary of the induction motor, the contacts of this relay supplying current to the electro-pneumatic switches. Should the circuit breaker open, or for any other reason the supply circuit to the primary of the induction motor be inter-
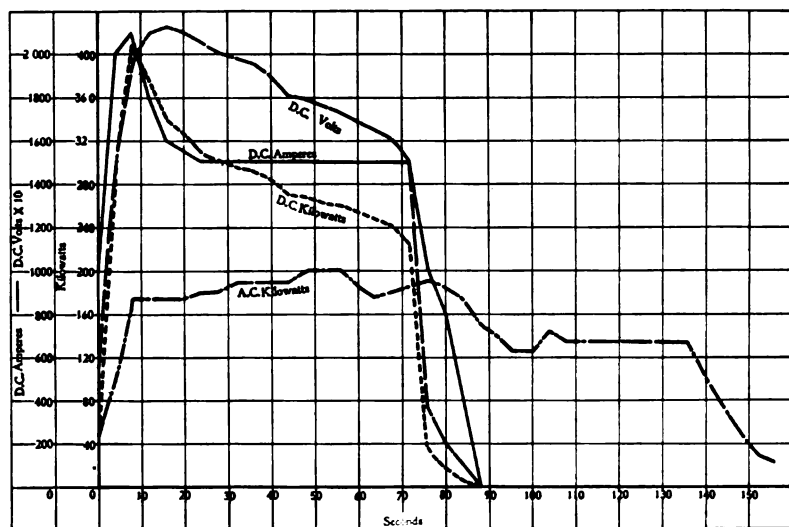

FIG. 7—CURVES PLOTTED FROM READINGS TAKEN WHILE HOISTING BUCKETFULL OF ORE FROM LOWEST LEVEL, EQUAL TO A VERTICAL LIFT OF 750 FEET, UNBALANCED

Relays set so as to operate the control switches when the alternating-current load reaches 170 kw.

rupted, this line relay opens, cutting off the direct-current power supply to the electro-pneumatic switches and thus causing all of them to open so that when the motor again starts it will have all of the resistance in the secondary circuit and the acceleration will be automatic.

The direct-current for the electro-pneumatic switches comes from two sets of storage batteries, either or both of which can be used at the same time, the object of the two sets being to allow one to be charged while the other is in service. The air supplied in this installation for operating the switches is taken from

the main supply for the entire plant. However, a small individual motor-driven compressor outfit can be employed for this purpose in an isolated plant where desirable.

The motor-generator set is started by closing the circuit breaker on the switchboard which causes the induction motor to start with all of the secondary resistance in circuit; the current relays preventing the cutting out of this resistance until the line current has
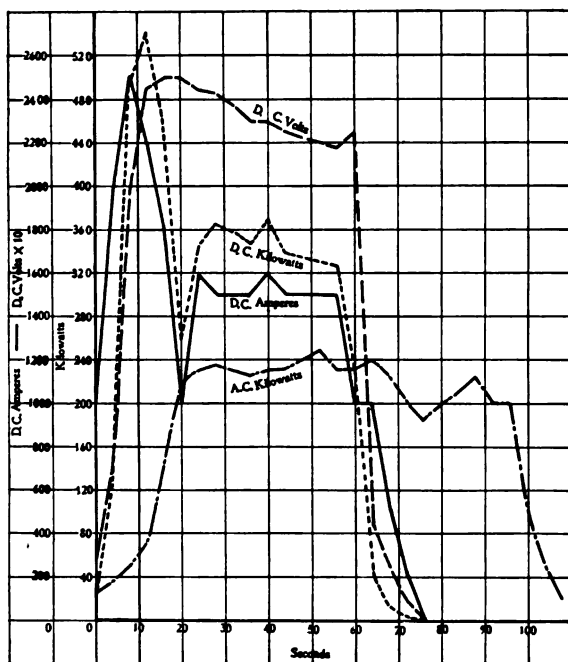
FIG. 8—CURVES SHOWING CONDITIONS WHEN HOISTING BUCKET OF ORE FROM NEXT TO LOWEST LEVEL, UNBALANCED
Relays set to operate on about 225 kw alternating-current load.

dropped to the proper value. The first three or four of the electro-pneumatic switches are for use in starting the motor, and in operating it they are seldom, if ever, in use. The circuit breaker between the exciter and the motor and generator fields is left open until the set has reached full speed.

The drums of the hoist are eight feet in diameter and the single reduction gearing between the motor shaft and hoist drums has a gear ratio of 6.2 to 1. The test curves shown in Figs. 7, 8, 9, 10

and 11 are plotted from readings taken by Mr. E. L. James, the erecting engineer, at which times the hoisting conditions were:

Normal speed of hoisting, 900 ft. per minute.
Weight of skip . . . .   3 845 lbs.
Weight of ore . . . .   7 000 lbs.
Weight of cable . . . .   600 lbs.

Total load . . . .   11 445 lbs.

In Figs. 7 and 8 the conditions during hoisting are shown. Some time is lost at the start in getting up to speed and the skip is slowed down within 60 or 70 feet of the top to insure an accurate stop at the exact point desired, as the skips are self-dumping
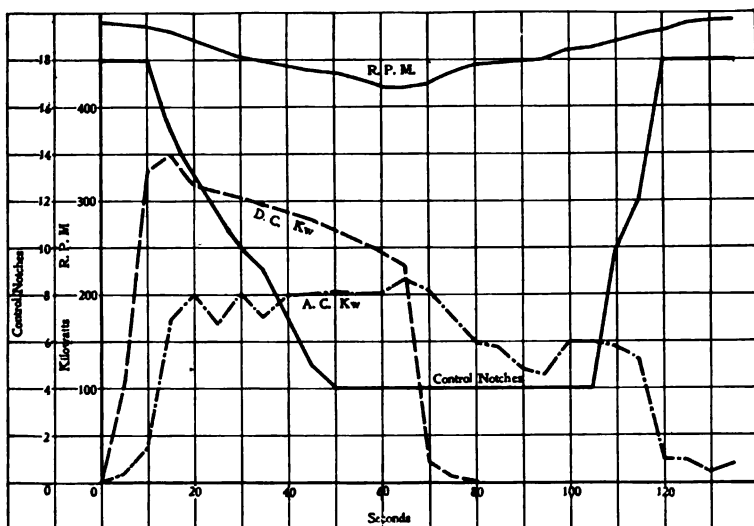

FIG. 9—CURVES SHOWING OPERATION OF RELAYS ON CONTROLLER

The resistance in series with the field of the hoist motor is adjusted so as to give a speed slightly above 225 r.p.m. at no load in order to allow for the drop in speed at full load.   In the tests made the relays were set to allow the unit switches to begin cutting in the resistance in the secondary of the alternating-current motor when its load had reached 250 kw.   With the relays thus set it was not considered practicable to adjust the generator field resistance so as to allow for the drop in voltage, inasmuch as in the case of lowering an empty bucket the generator voltage might reach too high a value.   Advantage may be taken of the fact that when lowering buckets the hoist motor feeds back to the motor-generator set and thence to the alternating-current line.

In all tests made, as well as at all times since during the operation, the commutation of both the direct-current generator and hoist motor has been absolutely perfect and most satisfactory operation has resulted. Since its operation no repairs whatever have been made outside of the usual attention given to the brushes of any direct-current machine.

The tests shown in Fig. 9 are interesting, as showing
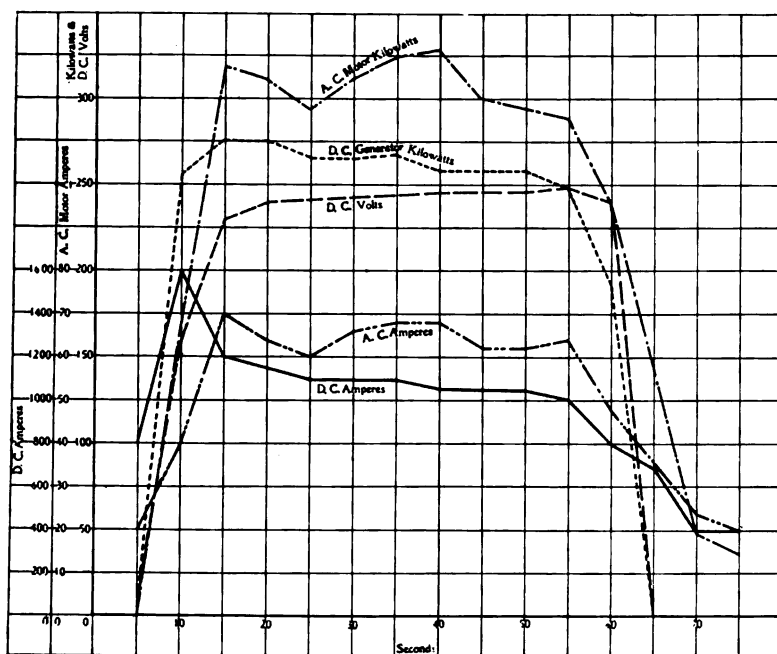
FIG. 10—TEST MADE WITH AUTOMATIC CONTROL CUT OUT AND MOTOR COLLECTOR RINGS SHORT-CIRCUITED

the drop in speed of the set as the load comes on the hoist, at the same time showing this speed change in connection with the automatic switches operating on the resistance in the secondary of the alternating-current motor. Fig. 10 shows what the operation is with the motor on the set running as an ordinary induction motor. In this test the automatic introduction of slip in the motor is not taken advantage of, consequently the stored energy in the fly-wheel is not utilized.

The set consumes approximately 25 kw when running empty and with the power shut off it will rotate for over an hour before coming to rest. For this reason a brake attachment is provided

which stops the set in less than five minutes when a shut down of any length of time is to be made.

FIG. 11—CURVES SHOWING OPERATION OF HOIST ENTIRELY BY FLY-WHEEL EFFECT OF THE SET
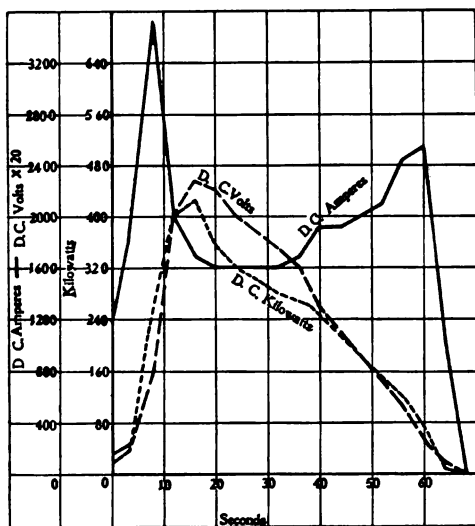
Alternating-current power was cut off at the instant the test was begun.

Another advantage of this system, which should not be lost sight of, is the possibility of working the hoist for a short time, in case of emergency, after the power has been suddenly cut off the line by accident or otherwise. This feature is shown by the test curves in Fig. 11 and is especially valuable in cases where a blast has been set and the men below are depending upon the hoist to reach the upper levels. It is for this reason that the exciter is driven from the set instead of separately, in order that the exciting voltage may be maintained as long as sufficient momentum remains in the set to generate current. In this test it is to be noted that the alternating-current breaker was opened at the instant the test was begun and that full load was lifted corresponding to a vertical height of 595 feet. With the skip loaded with men the distance would have been very much greater.

The costs of the hoisting with this outfit have been very satisfactory, amounting to but seven cents, Mexican money, per 1 000 foot-ton; the former cost of hoisting by steam having been many times the present cost by electric power.

ILLUMINATION COST FACTORS*

MAX HARRIS

IN investigating the cost of operating lighting systems, in order to determine which system has the lowest operating cost, the following factors should be considered:

1—Efficiency or cost of current consumed.

2—Cost of renewals or maintenance.

3—First cost or investment.

Investment is placed last, because any difference in first cost that is justified, is based on the relative total cost of operation consisting of items 1 and 2. One method in vogue is to determine costs on the basis of cost per candle-hour. At once the question arises, what is meant by candle-hours, and in fact we are immediately plunged into a discussion as to what is the correct method of rating light sources. Some contend that the only correct basis of comparison for all purposes is the consumption of current per mean spherical candle-power, others, mean hemispherical candle-power. What matters it which contention is correct so far as practical results in illumination are concerned? What is important and essential is not to determine the relative efficiency of the light sources employed to obtain good illumination, but the relative efficiency of the various systems employed. In an article on "The Problem of Efficiency in Illumination,"† Mr. Arthur J. Sweet covers the ground thoroughly, pointing out the importance of properly installing and equipping light sources so as to obtain good illumination, and further pointing out that at the present time we have no "unit of efficiency" for comparing the efficiencies of various systems of illumination other than to compare the amount of energy required by various systems to produce equivalent "good illumination" for similar areas under similar conditions. It is to be regretted that Mr. Sweet did not give data on the efficiency of systems, in view of the fact that he closes an otherwise very able article by furnishing a table of efficiencies of various light sources, based on their mean spherical efficiency, which table, however, may be considered by many as an indication as well of the relative illumination efficiencies of the various light sources mentioned.

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*From a lecture delivered at The Electric Club, on May 3rd, 1909.
†In the JOURNAL for March, 1909.

Many able papers have been written fully describing what is meant by good illumination, and outlining various methods of obtaining good illumination. A recent paper by Mr. J. R. Cravath covers the ground and points out the advantages and disadvantages of direct and indirect systems of illumination.

Several years ago Prof. A. J. Wurts suggested that the proper method of determining the relative illumination efficiencies of various light sources was by strictly comparative methods. Slowly but surely this method is coming into vogue. At the present time tungsten lamps are being offered in connection with prismatic reflectors with claims, for the different combinations as systems of illumination, of certain mean hemispherical efficiencies, with the further recommendation that they be installed on the basis of so many "lumens per watt" or, to obtain a desired quantity of illumination, there must be employed or used a specific quantity of current per square foot of area to be illuminated. The manufacturers represent for the tungsten system (clear lamps and clear reflectors) that to obtain an illumination of four-foot candles in a large room having light walls and ceiling, it is necessary to use one watt of energy for every square foot of floor area to be lighted, and that, under similar condition using the same type of lamps, but instead of using a clear prismatic reflector an enameled prismatic reflector, (although the mean spherical efficiency of the light source remains the same) the illumination efficiency of the system has been decreased and it becomes necessary to use one and one-sixth watts per square foot to obtain equal illumination. This may be carried a little further by assuming that it is desired to light an area of 100 by 100 feet, used for commercial purposes and wired one outlet per bay, that the intensity on the plane of reference is to be four foot-candles and that several systems are to be considered as follows:

1—Tungsten lamps equipped with clear prismatic reflectors.

2—Tungsten lamps equipped with enameled prismatic reflectors.

3—Tungsten lamps as used in the "I" comfort system.

4—Westinghouse Nernst lamps equipped with alabaster balls.

5—Direct-current enclosed arc lamps.

According to the table of efficiencies in Mr. Sweet's paper, the efficiencies of these various light sources, or the number of candles per kilowatt are in the following order:

1—Tungsten lamps.

2—Direct-current enclosed arc lamps.

3—Westinghouse Nernst lamps.

If these figures were based on mean lower hemispherical efficiency the following would be the order:

1—Tungsten lamps with clear prismatic reflectors.

2—Westinghouse Nernst lamps.

3—Tungsten lamps with enameled prismatic reflectors.

4—Direct-current enclosed arc lamps.

5—Tungsten lamps with "I" comfort reflectors.

As the result of many tests of commercial installations, coupled with data furnished by manufacturers, it has been found that the wattage required to illuminate the space considered would be as follows:

1—Westinghouse Nernst lamps with light opal ball, 108 000.

2—Tungsten lamp with clear prismatic reflectors, 108 000.

3—Tungsten lamps with enameled prismatic reflectors, 124 000.

4—Tungsten lamps "I" comfort system, 144 000.

5—Direct-current enclosed arc lamps, 148 500.

Here again it will be noted that although in cases *2*, *3* and *4* lamps having a mean spherical efficiency of 1.62 watts per candle were employed, that on account of their treatment in cases *3* and *4*, the consumption of energy required was greater than in case *1*, where Westinghouse Nernst lamps were considered having a mean spherical efficiency of 2.25 watts per candle.

For all practical purposes, therefore, the efficiency of the 220 volt Westinghouse Nernst lamps for interior illumination may be placed as being equal to that of the tungsten system consisting of a combination of clear prismatic glassware and tungsten lamps operating at 1.25 watts per mean horizontal candle-power. The above figures are based on new lamps and reflectors, and no allowance made for depreciation in illumination due to decrease in candle-power of light sources or from dirt accumulating on the reflecting devices.

Again if it is desired to reproduce the quantity of illumination in this room with either Westinghouse Nernst or tungsten lamps, what should be known is not so much the efficiencies of the lamps themselves, but of the systems under consideration. Therefore, in determining the cost of current, it should be based on the wattage consumption for equal illumination, or the relative illumination ef-

ficiencies of the systems, regardless of the efficiencies of the light sources employed.

<div align="center">COST OF RENEWALS OR MAINTENANCE</div>

Too little consideration is given this most important subject. It is immaterial whether it costs 0.5 or 2.5 cents per kw-hr. or per c-p-hr. to maintain a high efficiency system, such as the tungsten, when considering it in competition with low efficiency systems, such as the carbon filament systems, but it becomes a very important factor when considering the relative cost of operation of two high efficiency systems, whose illumination efficiencies are approximately equal. It is the author's belief that the proper method of computing renewal costs is on the basis of cost per kw-hr. Energy consumed by lighting systems is generally metered, and the buyer of current for illumination purposes, especially in this country, has been educated to purchase it at a rate per kw-hr. He knows what that means. He would readily understand a proposition to maintain an installation of lamps at 0.5 cents per kw-hr.

Assuming that a user of current were considering the installation of ten four-light clusters equipped with 100 watt tungsten lamps, or ten three-glower Westinghouse Nernst lamps and wanted a guarantee on the cost of upkeep. Having satisfied himself that the illumination from either proposed system was satisfactory and knowing that he would have to pay for current consumed at ten cents per kw-hr., he could readily understand a guarantee of 0.5 per kw-hr. Presuming that he was guaranteed an average life of 800 hours from each tungsten lamp and a cost of $1.20 per lamp, the rate for tungsten lamp maintenance would figure out 1.5 cents per kw-hr.

Before going further into this question of cost, it is well to consider what is meant by renewals or maintenance. Does it mean simply the cost of lamp renewals? With many salesmen of incandescent lamp units that is just what it does mean, but as a matter of fact the cost of lamp renewals is only one item in the cost of maintenance. The labor item is an important one, and labor to periodically clean lamps and reflectors is just as essential to the maintenance of good illumination efficiency in incandescent lamp systems as it is in the case of arc and Nernst systems which are periodically inspected and cleaned, as well as renewed when necessary. It is a fact that any system, which because of its design and inherent characteristics demands periodical inspection accompanied

by periodical cleaning of diffusing or reflecting apparatus, will deliver a higher mean illumination efficiency than a system which does not because of its design make periodical inspection a necessity.

In the case of systems employing prismatic reflectors, it has been found, as the result of tests, that decreases in illumination reaching as high as 40 percent occur, due to failure to clean the reflecting surfaces, so that not to employ labor to clean such systems means loss in efficiency, and, when this is recognized and labor is employed, it becomes an item in the total cost of upkeep.

As an example of what this means, there are employed in a large mercantile establishment four men who maintain an installation of 5 200 Nernst lamps. Each lamp has one piece of glassware. Any incandescent system employing prismatic reflectors would require at least twice this number of pieces of glassware, and as in many bays large units are employed which would require the use of two or more units to replace the present ones, it is estimated that instead of having 5 200 pieces of glassware to keep clean (if not only from an efficiency standpoint at least from a hygienic standpoint) there would be at least 12 500 pieces of glassware to keep clean.

The cost of maintenance does have an important bearing on the cost of illumination, even where there is a marked difference in illumination efficiencies when cost of current is low. For large propositions it is useless to consider current at eight or ten cents. In the case of large department stores, in most of our northern cities, current is purchased at from 2.25 to four cents per kw-hr. In a recent instance a department store using five ampere direct-current enclosed arc lamps, after making tests with Westinghouse Nernst and tungsten lamps, decided that it was possible to replace the enclosed arc lamps with either tungsten lamps or Westinghouse Nernst lamps by substituting for each arc lamp (consuming 550 watts) a unit or units consuming approximately 400 watts. Current was purchased for 2.6 cents per kw-hr. without maintenance and the enclosed arc lamps were to be maintained at 0.4 cents per kw-hr. if retained The Westinghouse Nernst lamps were to be maintained under agreements at 0.65 cents per kw-hr. and tungsten maintenance was 1.5 cents per kw-hr.

The following are the resultant cost figures per hour:

Arc lamps.................. 550 watts at 3c   per kw-hr. = $0.0165 per hr.
Tungsten lamps. 400   "   " 4.1c "   "   = 0.0164   " "
Westinghouse Nernst lamps. 396   "   " 3.25c "   "   = 0.01287 " "

The average hours' use of the lamps per year was estimated at 1 500 hours, so that the Westinghouse Nernst system indicated a saving of $5.44 per lamp per year over the enclosed arc lamp, whereas the tungsten system showed no saving where the intensity of illumination from the enclosed arc lamps was the set standard of illumination. Large installations of alternating-current Nernst lamps are maintained by the manufacturers at a rate of 0.4 cents per kw-hr. and direct-current installations at 0.6 cents per kw-hr.

Assuming a life of 800 hours for each tungsten lamp purchased, and not considering any charge for labor the user would have to purchase tungsten lamps at prices indicated in Table I to place the two systems on an equality so far as total cost of operation is concerned.

TABLE I.

Size.	Life.	Kw Consumption during Life.	Tungsten lamps vs.	
			D. C. Nernst.	A. C. Nernst.
25 Watt	800	20	$0.12	$0.08
40 "	800	32	0.192	0.128
60 "	800	48	0.288	0.192
100 "	800	80	0.48	0.32
250 "	800	200	1.20	0.80

First cost or investment should be considered purely from the standpoint of earning power. In the determination of this question, however, due consideration must be given to the possibilities of the future, but in view of the present high illumination efficiencies of the latest systems, with the consequent low cost of illumination, the buyer is justified in basing his determination on obtaining five years' service from any system before replacing it with a new system that may have either higher efficiency or may appeal to the buyer for other reasons. So far as replacing a system by another of higher efficiency, the new system would have to show a sufficient saving to justify a further investment and would therefore be judged on its own merits. Again the history of the art indicates that five years is only too short a period between the perfection of one system and the advent and perfection of newer systems. Enclosed arc lamps have been in service for over ten years and in many cases on account of short burning hours and low cost of cur-

rent, the saving that might be effected by changing to one of the newer systems would not justify the investment, providing, of course, the quality of the illumination from the arc system was satisfactory.

In the case of the department store before referred to, on account of the long burning hours a good saving was indicated, yet some users would not consider the saving sufficient to justify the investment. Assuming that the investment in this instance was $12.00 per outlet, if interest be figured at five percent it would take two years and six months to earn the investment, but thereafter there would be a net saving of $5.44 per outlet per year, or if the user decided that a 20 percent depreciation charge per year would be a reasonable one, the figures would indicate an annual saving of $2.44 per outlet per year. Again, if we assume that the proposed tungsten installation would have cost from $2.00 to $5.00 per outlet less than the Westinghouse Nernst, the additional cost would be more than justified by the additional earning power of the Westinghouse Nernst units.

While on the subject of investment and first cost it seems advisable to say a few words to clear up what is a general misunderstanding of the first cost of Westinghouse Nernst lamps. Because of the general knowledge that a 100 watt tungsten lamp can be purchased for from $1.25 to $1.75 per lamp, and smaller sizes at lower prices, the impression prevails that it is a low first cost system, whereas the Westinghouse Nernst lamps, because the single glower units are listed at $7.50, are generally believed to be a high first cost system. Where small units are to be used, although there is some difference between the cost of the single glower lamps and the 100 watt tungsten unit when equipped with a prismatic shade, even this difference disappears when a comparison of the large Westinghouse Nernst units are made with the equivalent wattage of the tungsten equipment required. For example, four 100 watt lamps equipped with prismatic reflectors sell for approximately $8.00. To this must be added the cost of a four-light fixture or cluster. Any cluster or fixture which would be in keeping with the design and appearance of the three-glower Westinghouse Nernst unit costs from four to six dollars, so that we have a total cost of from twelve to fourteen dollars for the tungsten equipment. The three-glower lamp lists at $22.50 and this with a minimum discount of 45 percent makes the maximum price to the consumer $12.37.

Again, the Nernst Company is marketing a four-light chandelier equipped with four 88 or 110 watt burners and is selling them at approximately $15.00, and any combination of tungsten lamps, reflectors and fixtures of equal quality, would cost at least as much.

In conclusion, Tables II and III are given, indicating the methods used in figuring the cost of illumination of two assumed propositions. A study of the tables will illustrate the points made.

TABLE II—PROPOSITION 1—DRUGSTORE

Installation consists of ten five-ampere direct-current enclosed arc lamps, furnished free by the lighting company (tests having determined that either a four light cluster of 100 watt tungstens or a three-glower Westinghouse Nernst should be employed). Rate for current four cents per kw-hr., which includes arc lamp maintenance. Net price of current 3.6 cents per kw-hr. Burning hours 3 000 per year.

1—10 Arc lamps at 550 watts = 5 500 × 3 000 hrs. = 16 500 kw-hrs. @ 4c = $660.00.

2—10 Tungsten clusters at 400 watts = 4 000 hrs. × 3 000 hrs. = 12 000 kw-hrs. @ 5.3c = $636.00.

3—10 3-Gl. W. N. lamps at 396 watts = 3 960 × 3 000 hrs. = 11 880 kw-hrs. @ 4.25c = $504.90.

First cost—Tungsten, $120.00—Saving per year with tungsten........$ 24.00
First cost—W. Nernst, $123.70—Saving per year with Nernst......... 155.00

TABLE III—PROPOSITION 2—WHOLESALE GROCERY HOUSE

Same conditions as to installation of lighting units. Cost of current ten cents, including arc lamp maintenance. Net cost of current 9.5 cents. Hours burning 360 per year.

1—10 Arc lamps 550 watt = 5 500 × 360 hrs. = 1 980 kw-hrs. @ 10c = $198.00.

2—10 Tungsten clusters 400 watts = 4 000 × 360 hrs. = 1 440 kw-hrs. @ 11.2c = $161.28.

3—10 W. N. 3-Gl. lamps 396 watts = 3 960 × 360 hrs. = 1 425 kw-hrs. @ 10.15c = $144.63.

First cost—Tungsten, $120.00—Savings with tungsten per year........$36.00
First cost—W. Nernst, $123.70—Saving with Nernst per year.......... 54.00

SELF-STARTING SYNCHRONOUS MOTORS

JENS BACHE-WIIG

T
HE use of synchronous motors for service previously per-
formed almost exclusively by induction motors has largely
increased recently owing to the beneficial effect of syn-
chronous motors on systems having low power-factors. In most
cases the motors have been made self-starting on account of the
simplicity of this method. The increasing use of self-starting motors
for a great variety of purposes involving widely different starting
conditions makes the question of starting performance of much im-
portance. Polyphase synchronous motors can be made so that they are
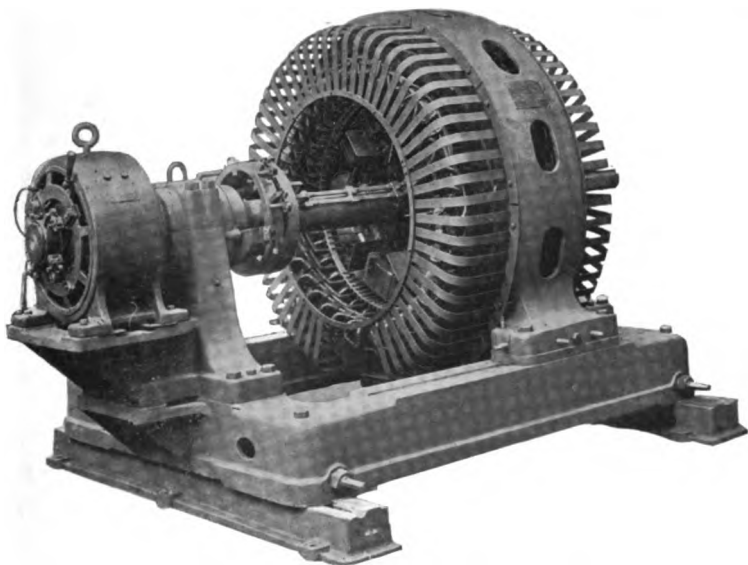

FIG. I—SELF-STARTING SYNCHRONOUS MOTOR WITH DIRECT-CONNECTED EXCITER
250 k.v.a., 25 cycle, 6 300 volts, 500 r.p.m.

self-starting in the same manner as induction motors of the squirrel
cage type. This is usually accomplished by the use of a cage wind-
ing similar in construction to that used for induction motors. The
bars of the cage winding are placed in slots punched in the caps of
projecting field poles, and the ends of these bars are joined together
by means of continuous rings. The only difference, therefore, be-
tween such a winding and a cage winding on an induction motor is
that the bars are omitted in the spaces between the poles. These

open spaces may cause "dead points," i. e., the motor may not start equally well for all positions of the rotor. However, if the rings extend all the way round, thus joining the poles together and if the pole caps cover from 75 to 80 percent of the pole pitch, dead points are practically eliminated.

In case an alternating electromotive force is applied to the armature winding of such a motor, currents will flow and a magnetic flux will be set up in exactly the same way as in an induction motor. This flux, cutting the bars of the cage winding, will set up currents in them and develop a torque proportional to the square of the current in the cage winding and its resistance. Besides this main torque, there will be torques set up by hysteresis and by eddy-current losses in the field iron, and these will materially assist the torque produced by the currents in the cage winding in bringing the motor up to speed.

These several torques follow different laws with increase of motor speed. The torque due to the currents in the cage winding, on account of the relatively low resistance of this circuit, will be small at standstill, will rapidly increase as the speed increases reaching a maximum at a point not far below synchronous speed, and will then more rapidly decrease, becoming zero again at synchronous speed. This is the familiar speed-torque curve of an induction motor with a low resistance cage winding. The torque due to the eddy currents in the rotor core, while produced in the same way as the torque due to the cage winding, will vary differently with speed on account of the high resistance of the iron core compared with the copper cage winding. The torque will be maximum at standstill and will decrease gradually with increase in speed following the same law as an induction motor with a high resistance cage winding. The torque due to hysteresis will remain approximately constant until synchronous speed is reached when it suddenly drops to zero.

It is not difficult to understand how the synchronous motor starts by means of the several torques just described. It is somewhat more difficult to understand, and to explain, how the motor "pulls into synchronism," how it overcomes the slip, considering its action as an induction motor. There is an essential difference between the synchronous motor and induction motor in that the synchronous motor, although it starts exactly as an induction motor, goes a step beyond the induction motor and pulls into synchronism. It does this even before there is any field excitation, before there is any additional element that would obviously explain the difference

in operation. However, the difference in operation can only be explained by some difference in construction. The most plausible reason is the difference in the magnetic circuits of the rotors. In the induction motor the rotor presents a uniform face to the armature and a uniform magnetic circuit. In the synchronous motor the rotor has projecting poles so that in some positions the magnetic conditions are mo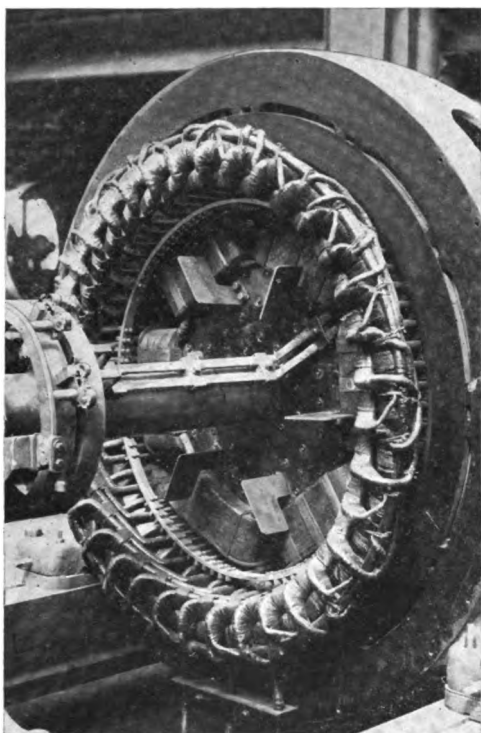re favorable than in others. The magnetic flux set up by the primary current tends to close itself through the field core in such a way that the magnetic resistance of the circuit becomes a minimum. This is the case every time a projecting field pole is opposite a magnetic armature pole; when the field pole drops behind the armature magnetic pole, the resistance increases and is a maximum when the field pole is halfway between armature poles. At synchronous speed the relative rotation between the field and the armature becomes zero, the field poles remain opposite the magnetic armature poles, the flux becomes a maximum and tends to hold the field in this position. The torques already described will bring the rotor up to full speed and the action of the magnetic field toward the projecting poles of the rotating field will cause the latter to lock in synchronism and hold it there.

FIG. 2—DETAILS OF WINDING OF STATOR AND ROTOR
View of same machine as shown in Fig. 1, taken from exciter end of motor with end bells removed.

It will be seen from the above that it is important that the speed of the rotating field be brought up as near as possible to synchronous speed in order that the field shall lock in synchronism. In

other words, it is necessary to make the resistance of the cage wind-
ing small. This, however, is antagonistic to a condition of large ini-
tial starting torque. The cage winding further acts as a damper
during operation to prevent hunting and this requires a certain
amount of copper in order that the damping shall be effective. Thus
the design of the cage winding is necessarily a compromise between
the best starting performance on the one hand, and the ability to
pull into synchroism and the damper action on the other, since these
functions require opposite characteristics of the cage winding.

In all cases, during starting, the maximum torque required
will be either at the moment of starting, to overcome the static fric-
tion, as in the case of a motor-generator set, line shafting, or an
air compressor, or the maximum torque required will be near or at
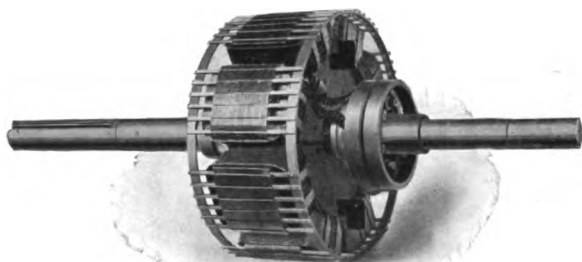synchronous speed as in the case of a centrifugal pump or fan. In

FIG. 3—ROTOR OF A SELF-STARTING SYNCHRONOUS MOTOR

the first case, with large initial starting torque the cage winding
can be designed with a greater resistance, to secure the necessary
initial torque without encountering difficulty at full speed, since at
full speed the required torque will be relatively small. Under these
conditions the starting current may be relatively small. In the case
of a motor driving a centrifugal pump or fan, the resistance of the
cage winding will necessarily be made small in order that synchron-
ous speed may be obtained. Fortunately, the torque required to
overcome the static friction is small compared with the required
torques at high speed, and the current at the moment of starting
will still be relatively small in spite of the cage winding of small
resistance. The starting current, however, will be greater than in
the first case.

Synchronous motors of this type are ordinarily designed to
develop a starting torque of about 30 percent normal running torque

with a current (from the line) of about one and one-fourth times normal rated current. The motor alone will require about 15 percent normal torque to start and the current from the line during starting will thus be less than the normal rated current. The time required for such a motor to reach synchronous speed will be about 30 seconds. In the case of a motor driving a direct-current generator, the starting torque required is approximately 15 percent + 15 percent = 30 percent and the current drawn from the line approximately one and one-fourth times normal current. The time required to start will be less than one minute. In the case of an air compressor the torque will be approximately 15 percent + 35 percent = 50 percent, and the current from the line less than twice normal current; synchronous speed will be obtained in about one minute. When the motor is connected to a fan, the load coming on as the speed increases and normal full-load torque being required

FIG. 4—POLE PIECE OF SYN-
CHRONOUS MOTOR

Showing slots for bar winding.

at full speed, the current drawn from the line will be from three to four times the normal current, depending upon the starting devices used. It is evident that such starting conditions require different devices from those first named.

A high voltage would be induced in the field winding during starting if the field circuits were left open, hence it is necessary to provide some means for taking care of this condition. In stationary field machines, such as rotary converters, the field coils can be divided into several groups so that they can be insulated to withstand the voltage induced in each group. In revolving field machines this is not feasible and some other means must be used. A double-throw field switch is provided, so that with the switch in the starting position the field winding and the field rheostat form a closed circuit, and with the switch in the running position the field winding is connected with the exciter. The field rheostat is left in the circuit with the field winding during starting to limit the current which would otherwise reduce the starting torque. With this starting arrangement it is not necessary to increase the field coil insulation or test voltage above that required by a corresponding generator. It is often recommended that the field winding be insulated for 5 000 volts insulation test and left open during starting. As the voltage induced in the field coils at starting may be even greater than this

voltage, it is evident that the extra insulation does not afford proper protection in case the motor is started under these conditions.

The usual method of starting is by means of auto-transformers by which reduced voltage is applied to the stationary armature winding of the motor. The transformers are usually connected in V. For smaller motors and in cases where the starting torque required does not exceed 30 percent of the normal full-load torque, a double-throw switch, by means of which first the starting and then the running voltage is applied to the motor, will be sufficient. The starting voltage will be from one-third to one-half the full line voltage. At this voltage and required torque the motor will come up to the speed and lock in synchronism without field excitation. The field switch may then be closed on the exciter circuit and the exciting current adjusted to that corresponding to no-load, full voltage, whereupon the starting switch can be quickly thrown over to the running position without a noticeable rush of current. Large motors should have at least a three-point starting switch so that the voltage can be applied in steps of one-third, two-thirds, and full line voltage. This should be done in order to keep down the rush of current when throwing over from one step to the other. In case more than 30 percent normal torque is required, the number of steps should be increased for this same reason. In cases where a step-down transformer is used with the motor, taps giving the desired voltage can be brought out from the secondary winding and thus the auto-transformers omitted.

It is evident from the above that the starting performance of self-starting synchronous motors approximates that of induction motors with fairly low resistance, cage wound rotors. This naturally follows from the similarity in construction. It may be taken as a general rule, therefore, that self-starting synchronous motors can be applied where it is possible to apply cage wound induction motors with small slip, with the additional limitations in the case of the synchronous motor imposed by the necessity of overcoming the "slip" and pulling into synchronism. Where a phase wound induction motor with external secondary resistance must be used because a cage wound induction motor would not be satisfactory, then, for the same reason, a synchronous motor of the self-starting type would not be satisfactory and should not be used.

THE ILLUMINATION OF STREETS

C. E. STEPHENS

WHILE the advances have not been uniform, the art of illumination often remaining stationary for a time and at other times moving rapidly forward, the use of artificial light has progressed with our civilization until it seems to have reached an advanced stage of development. In fact the development along the lines of electrical appliances for the production of artificial light has been so rapid that it has become difficult for any one who does not make a special study of the subject to keep thoroughly posted. Thus the street lighting department of an electric lighting company is an important one and requires the attention of specialists in the art of illumination.

The problem in street lighting is to produce a uniform illumination of low intensity. This comprises the consideration of the light source, the light intensity, the distribution of the light flux, etc. It may not be amiss, therefore, to define the illuminating engineering unit in general use. The unit universally used in expressing the light intensity of any source is the candle. From recent scientific researches it has been determined that the mechanical equivalent of white light is approximately 0.07 watt per candle. This unit of light intensity is a unit ordinarily reproduced by comparison with maintained standards, and is the intensity of light from one standard British candle, which is a candle reproduced from specifications. The light intensity of a source in the majority of cases is not uniform, i. e., the intensity of light is different in different directions. It is common practice, therefore, in considering the merits of a light source for a particular service to refer to its distribution curve of light intensity, and in some cases to its mean spherical or hemispherical candle-power. The use of the candle-power for expressing the value of the light intensity at any particular angle, characterizes the distribution of the light flux for a particular purpose, but does not indicate the total flux of light from the light source.

The density of the flux of light is expressed in lumens and is the flux of light in a beam of one unit solid angle (one square meter at a radius of one meter) in which the intensity is 0.88 of a standard British candle. The light flux density is often expressed in terms of foot-candles, as its value is a function of the intensity and distance in feet.

Inasmuch as the result desired in street lighting is a uniform illumination of low intensity, the light flux should be distributed in a particular manner. When the height of the lamp and distance between lamps is considered, that source of light is preferred which gives the most of the light flux between the horizontal and 25 degrees below the horizontal. For the sake of economy it is of course desirable to select a lamp whose initial distribution of light flux is as near the desired value as possible, thus making it unnecessary to use reflectors.

A correct theoretrical arrangement of light sources to produce a uniform illumination does not necessarily mean a satisfactory illumination, since the results are in all cases judged by the effect produced. It is necessary to arrange the light sources in such a manner that the eye of the observer will not be exposed to their direct rays. If the intense rays of light emitted from the lamp are allowed to come within the field of vision, they cause the pupil of the eye to contract, thus limiting amount of light flux entering the eye from the objects which it is desired to distinguish. This is the reason for the difficulty experienced in clearly distinguishing objects beyond a street lamp. It is apparent, therefore, that theoretically more satisfactory street illumination can be obtained by decreasing the brilliancy of the light unit and placing it as high as practicable. Decreasing the brilliancy of light units ordinarily means that a greater number of lamps must be used.

By spacing small candle-power lamps near together, more uniform distribution of light may be obtained. At the same time the cost of installation and maintenance must be considered and this to a certain extent has a bearing upon the size of units selected. The use of a large number of small units increases the installation cost and, unfortunately in dealing with street lighting problems, municipalities in general regard the question of cost as of more importance than the quantity and quality of light.

In the thickly populated European cities the cost of street illumination per inhabitant is comparatively low, notwithstanding the fact that the standard of illumination is considerably higher than in the average American city. Further, the low labor cost abroad makes it possible to use flaming carbon arc lamps, the yellow light from which, on account of its high illumination intensity, is quite satisfactory. When it is necessary on account of cost to reduce the illumination to as small a value as is common practice in this country, the illuminating engineer is handicapped by the fact that he

must use a white light. The flaming carbon arc for street service also has been handicapped on account of its extremely high maintenance cost, particularly in this country where labor costs are comparatively high and the carbons used are expensive and of short life. Furthermore, the curve of light distribution is a maximum at a point directly beneath the lamp and it is, therefore, not suitable for producing uniform illumination.

A source of light giving an ideal distribution for street illumination is one producing no light in the upper hemisphere, whose maximum candle-power is at an angle approximately 15 degrees below the horizontal and whose minimum candle-power in the lower hemisphere is directly beneath the lamp. Such a distribution makes it possible to hang the lamp high, raising the arc above the direct line of vision, thus eliminating the glare in the eyes of people on the street, and at the same time maintaining a more nearly 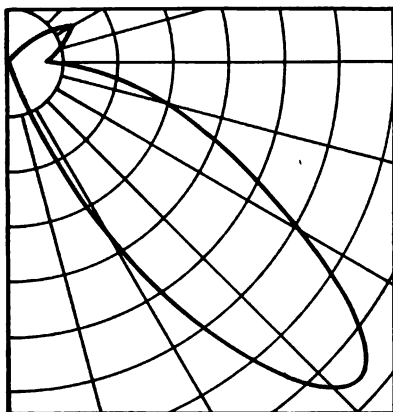uniform illumination of the street. Furthermore, in hanging the lamp high the shadows of objects along the street are shortened, the illumination directly under the lamp is reduced appreciably and the eye fatigue eliminated in that it then becomes unnecessary for the eye to adjust itself for the alternate bright and dark spots.

FIG. I—TYPICAL LIGHT DISTRIBUTION OF A DIRECT-CURRENT OPEN ARC.

In comparing the several types of electric light sources for street illumination they should be judged by the effective illumination produced at a point midway between adjacent lamps, i. e., at the point where the illumination intensity is of the lowest value.

Quite a great deal of confusion has been caused by the various methods used in rating arc lamps. In the early days of arc lighting an open direct-current arc lamp, consuming 9.5 amperes and 48 volts at the arc, was known as a 2 000 candle-power lamp. It was soon discovered that this rating was in error and the word "nominal" was added to the candle-power rating. So long as it was generally known that the term "2 000 nominal candle-power" was a mere

rating which applied to the only street lamp in general use, this method of rating was fairly satisfactory, since any two lamps of the same type and using the same carbons and consuming the same energy at the arc will give approximately the same amount of light at the same points on the distribution curve. The development of the enclosed type of carbon arc lamp, the high candle-power incandescent lamps and the metallic flame type of arc lamp has made it necessary to adopt other methods of rating lamps. It is quite difficult to make a satisfactory comparison of street lamps by using the old rating, since the later types of arc lamps such as the metallic flame lamp consumes only approximately 60 percent of the energy used in the open direct-current arc, and give far superior curves of light distribution for street illumination.

FIG. 2—TYPICAL LIGHT DISTRIBUTION OF AN ALTERNATING-CURRENT OPEN ARC.

The present practice of basing the comparison on the candle-power and the distribution curve of the light is a decided improvement over the old in that arc lamps are generally used for illuminating large areas, and if the shape of the light distribution curve is known, the calculation of the illumination which will be produced becomes a very simple problem. The various conditions which affect the light distribution, such as 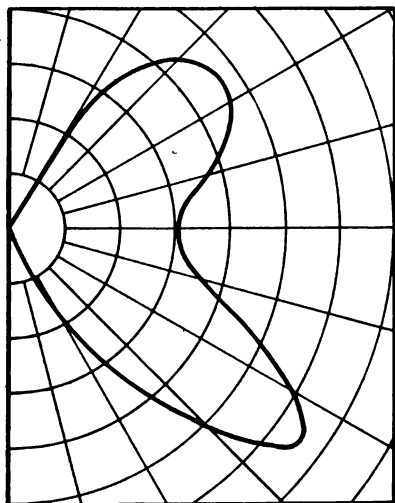the diameter, position and quality of the carbons, are so numerous that it is only possible to note the typical shape of these curves for the several types of arcs.

The typical shape of the light distribution curve for a direct-current open arc is given in Fig. 1. The maximum light is radiated at an angle of approximately 45 degrees below the horizontal. The light is emitted from the incandescent crater of the positive carbon, which accounts for the direction of the maximum candle-power. Very little light is emitted from the short non-luminous arc, and the light intensity near the horizontal is comparatively small. The use of this type of lamp for street service is very objectionable on account of the fact that it is almost impossible to approach a uni-

form illumination of the street. It produces a very disagreeable and dancing shadow immediately under the lamp, and an intensely illuminated area a short distance from the lamp, beyond which point there is comparatively no light.

The light distribution curve of an alternating-current open arc is approximately the same above and below the horizontal, as is shown in Fig. 2. The light radiated above the horizontal is useless for all practical purposes unless suitable reflectors are used to divert it downward. It is not practicable to design a reflector that will operate at a maximum efficiency with all positions of the arc throughout the life of a pair of carbons. Furthermore, there is always a loss in the reflection depending upon the material used for the reflector. It is apparent, therefore, that the alternating-current open arc for a street illuminant is inferior to the direct-current open arc.
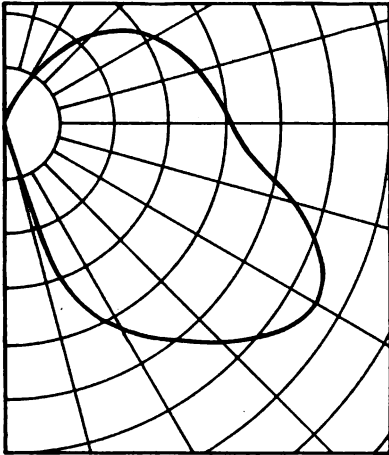
The development of the enclosed carbon arc resulted in a great operating economy, since the life of the carbon and the saving of labor in trimming and caring for for the lamps was greatly increased. A typical light distribution curve of the direct-current enclosed arc is given in Fig. 3. On account of the fact that in an enclosed arc

FIG. 3—TYPICAL LIGHT DISTRIBUTION OF A DIRECT-CURRENT ENCLOSED ARC WITH OPAL GLOBE.

the ends of the carbons are flat and have a comparatively large area. the crater can only occupy a small portion of this area at a particular instant. The distribution curve is consequently very irregular since the amount of light in a given direction varies with the position of the crater on the end of the carbon. In general the effect of this wandering arc can be eliminated to a great extent by the use of an opal enclosing globe which not only steadies the illumination, but decreases the intrinsic brilliancy of the arc. The development of the enclosed carbon arc was a decided advance regardless of the fact that the efficiency of the lamp as a light producer was considerably reduced. The energy consumption is the same as for the open arc, the total light flux is somewhat less; but

the curve of light distribution is considerably superior to that of the open carbon arc.

During the last few years we have been going back to the open arc principles to a very marked degree. Arc lamps have been developed which use the so-called flame carbon. The typical light distribution of the flame carbon lamp is given in Fig. 4. Lamps of this type produce large quantities of fumes and smoke, to dispose of which necessitates an open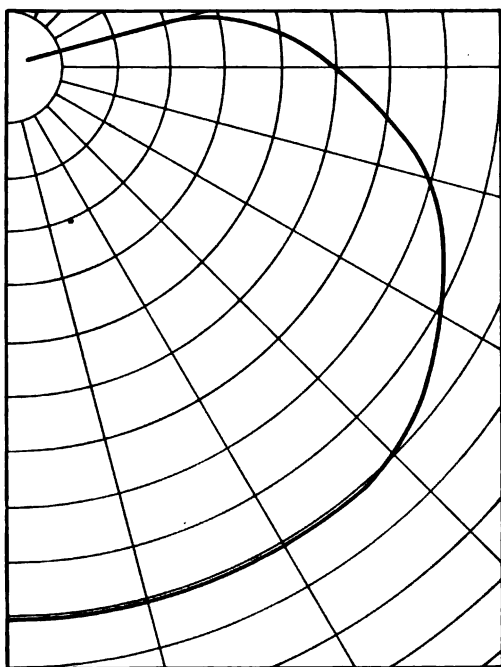 burning condition. The maximum light intensity is emitted directly under the lamp and it is quite impossible to produce a uniform illumination over a large area. Furthermore, owing to the short life of the carbons, the care and attention required is very large and the consequent high maintenance cost prohibits its use as a street lamp.

FIG. 4—TYPICAL LIGHT DISTRIBUTION OF A DIRECT-CURRENT CARBON FLAME ARC.

More recently there has been developed a type of arc lamp which consumes metallic electrodes. This lamp is of the flame type in that it has an open burning condition and the light emitted comes almost entirely from the luminous flame. This distribution of the light is shown in Fig. 5. The color of the light is almost pure white which has been found to be the ideal light for such low illumination intensities as are found in the average American municipality. Since the larger portion of the light comes from the flame, it is radiated near the horizontal, very little above the horizontal, and has a comparatively low value immediately under the lamp. The maintenance cost of this lamp compares very favorably with that of the enclosed carbon arc, and altogther it is the most important de-

velopment resulting from experiments having as their object an arc lamp of high efficiency with an almost ideal curve of light distribution for street illumination.

Regarding the various requirements of street lighting, it is the usual practice to classify the different districts as follows:

Business.

Residential.

Parks, etc.

The problem of properly illuminating the business section of a municipality is extremely difficult and the number of lamps, their position and height, etc., must be determined almost entirely by the local conditions. There can be no definite system or arrangement which will apply to all cities. The intensity of illumination should be higher than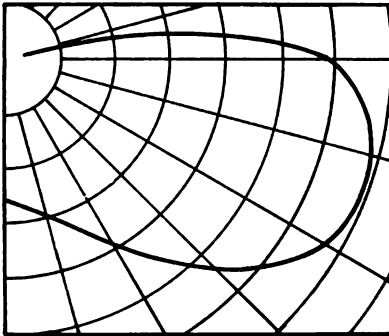 in residential districts on account of the congested traffic. The arcs in all cases should not be hung lower than 25 feet from the street. They should be as near the middle of the streets as possible, since the lights in the store fronts ordinarily illuminate the sidewalks sufficiently.

FIG. 5—LIGHT DISTRIBUTION OF A METALLIC FLAME ARC.

In residential districts the most serious problem to solve in properly illuminating the streets of any city is usually the one of avoiding obstructions, trees, etc. There are very few streets in our cities, particularly in the residential section, that are not lined on both sides with trees bearing dense foliage. For the majority of cases the use of low candle-power units along the curb would give satisfactory illumination. It is necessary, however, to hang the lamps low in order to clear the trees, which results in a high illumination of the walks in spots, and an objectionable glare is produced in the eye on account of the lamps being in the line of vision. If the lamps are supported near the middle of the street they can be raised considerably higher and still the light will not be obstructed by the trees. With this method of suspension the light is in the center of the area to be illuminated.

In the lighting of residential districts and parks particularly the illuminating engineer is further handicapped in his efforts to

give good illumination by the demand for ornamental poles and lamp
fixtures, the increased cost of which in too many cases subtracts
from the total appropriation for illumination, which in turn reduces
the light efficiency of the system.

Incandescent series lamps can be used very successfully in cases
where the result obtained are to be at a minimum expense, and
where the conditions will not permit of high candle-power units of
the arc type.

The service requirements of a series system of incandescent
street lamps are:

1—An efficient series lamp.

2—An efficient and satisfactory device for automatically regu-
lating the current.

3—Some automatic device for cutting out a lamp when the
filament breaks.

The recently developed tungsten incandescent series lamps are
a great improvement over the low efficiency carbon filament lamps.
The lamps are furnished in various candle-powers from 25 to 80
and give an average life of from 1 200 to 1 800 hours in commercial
service. They show but little reduction of candle-power during
their normal life, the quality of the light remaining excellent, and
the filament does not become yellow. There are in general use to-
day two systems of series tungsten lighting, the choice of which de-
pends upon the local conditions and to some extent upon the num-
ber of lamps to be installed. These are known as the "adjuster
socket" and "regulator" systems.

The adjuster socket system consists of a series of lamps con-
nected across the high tension alternating-current mains with an im-
pedance coil connected in shunt to each lamp for maintaining the
continuity of the circuit when a lamp burns out. The ampere
capacity of all the lamps in one series must be the same and the sum
of the voltages of the lamps must equal the voltage of the circuit to
which they are connected.

The regulator system differs from the adjuster socket system
in that the series of lamps is controlled by a constant current
regulating transformer which automatically controls the current of
the circuit. With this system each lamp is furnished with a socket,
the clips of which are insulated with a suitable insulating film,
which will withstand the voltage of the lamp. When the lamp fila-
ment breaks the full voltage of the regulator is impressed on the

insulating film which is punctured, thus short-circuiting the lamp and closing the circuit again.

In this connection it might be well to mention that considerable improvement has been made in the reflectors used with series incandescent lamps by which the effective illumination has been materially improved. The series incandescent lamp does not come into competition with the arc light which is required for different conditions of service. Its field of application is in outlying districts, parks, densely shaded areas, etc. It is in direct competition with gas lamps, and it has thoroughly demonstrated that it is far superior for these reasons:

1—On a basis of cost for equivalent illumination.

2—The incandescent series lamps give sufficient light under the lamps, whereas with the gas lamps there is practically none.

3—Where the lamps are to be widely scattered incandescent lamps can be installed more readily and at a less expense than a similar installation of gas lamps.

4—The light of incandescent lamps is white and for low intensities is superior to gas.

5—They can be lighted and extinguished from a distance.

6—They can be hung in the middle of the street.

7—Where it is necessary to support them over the sidewalk or curb, they can be hung high, while with the gas lamp this would be impracticable on account of increased cost of poles and the inaccessibility of the lamps for lighting and extinguishing.

AUTOMATIC CONTROL OF MOTORS OPERATING OPEN HEARTH TILTING FURNACES

AT THE WORKS OF THE JONES & LAUGHLIN STEEL COMPANY, PITTSBURG, PA.

I. DEUTSCH

T HE Jones & Laughlin Steel Company have recently completed the installation of four 225 ton open hearth furnaces. These are arranged in a continuous line in a large building known as "Open Hearth No. 3." A number of features of interest to electrical men have been included in this installation as it is almost entirely motor operated. Provision has been made for charging the
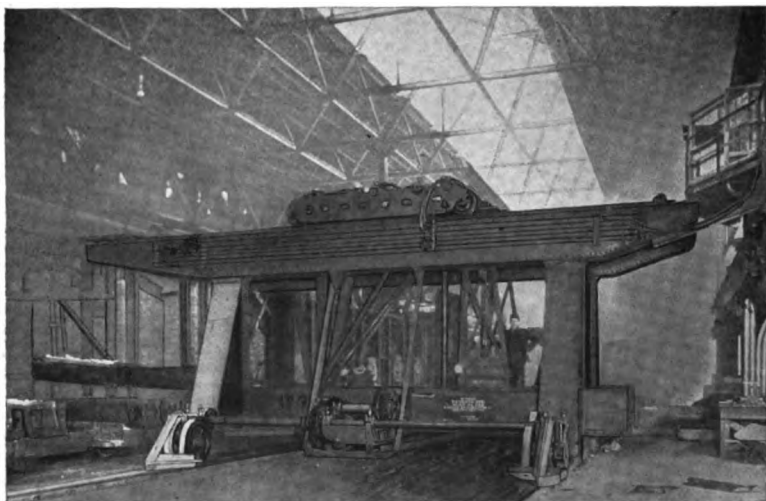

FIG. I—FLOOR CHARGING MACHINE FOR OPEN HEARTH FURNACE

furnaces either with molten metal from the blast furnaces or with scrap, or both. The furnaces are operated continuously, about 75 tons being poured at one heat. The iron is brought by locomotives from the blast furnaces in another building on ladle buggies to the mixers which serve as receptacles for the casts from several furnaces. From the mixers the charge is conveyed by ladle buggies to the open hearth furnaces. These furnaces are served by an overhead crane and by two floor chargers, one of which is shown in Fig. I. The crane is used to place the spout and tilt the ladle when

charging hot metal and the charging machines are used for placing the materials in the furnaces.

Each heat requires about six hours when, at a signal from the melter, a large casting ladle is placed, by use of an overhead crane, under the spout of the furnace on the opposite side from the charging floor, as shown in Fig. 2. The furnace is then tilted forward by electric motors until the ladle has been filled with 75 tons of hot metal, when it is again restored to the level position. The crane then conveys the ladle with its hot metal to the ingot moulds in which the steel is allowed to cool; after which the moulds are stripped from the ingots. The ingots are then carried as needed to the soaking pits to be heated preparatory to the process of rolling into finished products.

As only about one-third of the contents of the furnace is poured at one time and as the pour must be made without waste, the operation of tilting must be conducted very carefully and provision must be made for tilting the furnace back to its normal position promptly when the ladle is sufficiently filled. If any hitch should occur at this crucial step, it would be likely to result in the loss of a considerable portion of the charge before the trouble could be located and rectified. For this reason the tilting machinery and the device by which it is actuated and controlled form an exceedingly important factor in the construction and operation of such furnaces.

FIG. 2—VIEW IN BUILDING No. 3 SHOWING POURING END OF OPEN HEARTH FURNACE AND 100 TON CRANE EQUIPPED WITH AUTOMATIC MAGNET SWITCH CONTROLLERS

The ladle is used to convey the metal from the furnace at the right of the illustration to the ingot moulds.

Formerly hydraulic power was used to operate the tilting machinery, but recently electric motors have come into use for this purpose. In this particular instance the use of motors was decided upon on account of the elimination of trouble which might be experienced if the water in the pipe lines leading to the hydraulic cylinders should freeze, and also by reason of the necessity for exact parallel operation of the tilting machinery at each end of the furnace in order to avoid twisting stresses in the furnace structure.

A front view of one of the furnaces and the tilting machinery

FIG. 3—VIEW OF CHARGING SIDE OF OPEN HEARTH FURNACE
AT JONES & LAUGHLIN STEEL CO., PITTSBURG
The ladle is moved to position before one of the
charging doors by means of the shifting engine and is
tipped by means of the overhead crane.

is shown in Fig. 4. The foundations of the furnaces are of concrete sunk about 40 feet below the floor level and capped at each end of each furnace by bed-plates. These plates form tracks or runways for two series of steel rollers which support the entire weight of the tilting portion of the furnace. On each set of rollers rests a box girder built of I-beams which in turn supports segmental castings forming the supports for the furnace. Owing to the curved shape of these castings the furnace will be tilted by any lengthwise motion of the box girders. Motion of the furnace except around the desired axis is prevented by large flanged rollers jour-

nalled in bearings supported directly from the foundation and lo-
cated at the front and rear on the center lines of the end supports,
as shown in Fig. 4. This construction definitely fixes the center of
rotation relative to the stationary parts and thus facilitates the ar-
rangement of the inlet and outlet ports at the ends of the furnace
through which the gas and air are introduced from the re-heater
and drawn off after combustion has taken place above the surface
of the metal. A steel screw is journalled in bearings between each
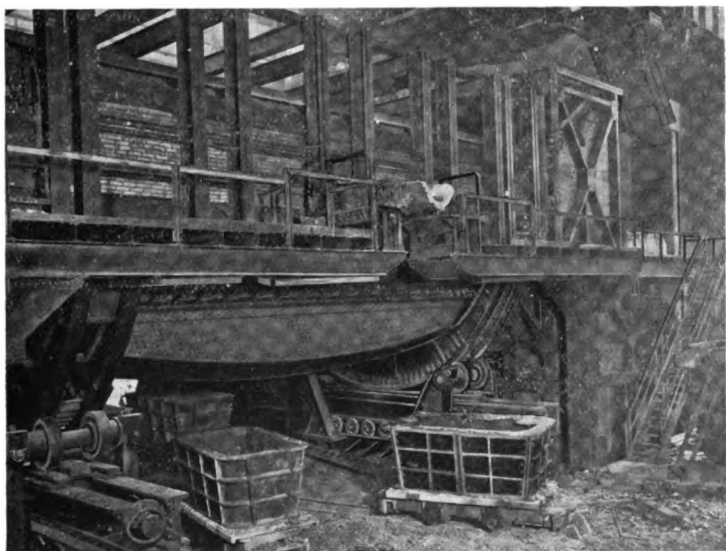pair of I-beams forming a box girder and held by thrust bearings

FIG. 4—VIEW SHOWING ARRANGEMENTS FOR TILTING OPEN HEARTH
FURNACE

so that no lengthwise motion can take place. The screw engages
a nut which is trunioned to the I-beams so that when the screw is
rotated the girder is moved forward and backward, depending upon
the direction of rotation of the screw. Two motors are connected
to one end of each of these screws as shown in Fig. 5. By operating
these two sets of motors the furnace may be tilted in either direc-
tion; when the motors are started forward the girders are moved
inward thereby tilting the furnace forward; by reversing the motors
the furnace may be tilted backward.

The motors each have a capacity of 30 horse-power at 220
volts and are connected two in parallel to each screw. The four

motors are operated and controlled by an automatic magnetic
switch controller, Fig. 6, provided with two master switches and
an interlocking switch. Each master switch is so connected that
when its handle is turned in one direction the furnace is tilted, and
by reversing the furnace may be restored to the normal level posi-
tion. One of the master switches is located on the front side of the
furnace so that the operator will be in a position to watch the pour-
ing of the cast. The other master switch is at the rear where the
operator can watch the tilting of the furnace to run off slag and
facilitate charging with hot metal. The interlocking switch is so ar-
ranged that only one master switch is in circuit at one time. This
makes it impossible for two operators, located at the respective mas-
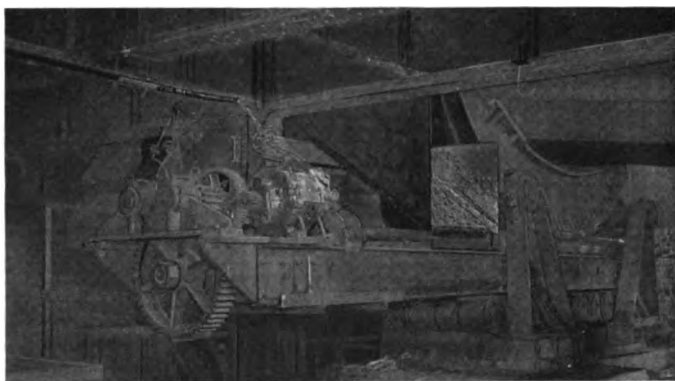

FIG. 5—DETAILS OF TILTING ARRANGEMENT UNDER ONE END OF
FURNACE, SHOWING MOTORS

ter switches on the opposite sides of the furnace and out of view
of each other, to operate both switches at the same time.

   Referring to the diagram of connections of the outfit, Fig. 7, it
may be seen that the armatures of motors *1* and *2* are connected in
parallel and included in the circuit with a series limit relay, *A*, and
a starting resistance, R_5-R_1. The armatures of motors *3* and *4* are
similarly inter-connected with a relay, *B*, and a resistance R'_5-R'_1.
The fields of all four motors are connected in parallel, as shown.
When it is desired to tilt the furnace forward at minimum speed,
the handle of the master controller No. 1, for example, is thrown
to the forward contact *U-1*. In the diagram, the interlocking
switch is shown as a "developed" drum controller, all shaded rec-
tangular contacts being mounted on the drum and moving with it.

With it set in position C, magnet switches *2* and *4* will close and current will pass from the positive line to contact S_2 on switch *2*, through the four fields to S_1 on switch *4*, then through the starting resistances, limit relays and motor armatures to the negative line. The motors will now run at lowest speed forward.

To obtain moderate acceleration, the handle of master switch No. *1* is thrown to contact *2*, when switches *5* and *5_a* will close and cut out sections R_2-R_1 and R'_2-R'_1 of the starting resistance. This operation may be continued, if desired, until all of the starting resistance is cut out or, as is customary, the master switch handle may be thrown from the off position to full-on (contact *5*), and the motors will automatically accelerate to full speed as follows: Line switches *2* and *4* close first, as already mentioned, and the motors start. The starting current is sufficient to lift the relays A and B and open circuits *33-34* and *51-52*. As the motors accelerate the current decreases until the relays drop and again bridge the contacts *33-34* and *51-52*. Switches *5* and *5_a* then close and cut out sections R_2-R_1 and R'_2-R'_1 of the starting resistance, which causes a current rise sufficien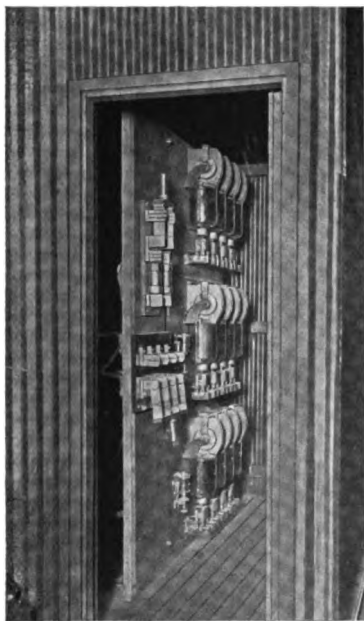t to again lift the relays. When the current reaches the normal value the relays drop and switches *6* and *6_a* close, thereby short-circuiting sections R_3-R_1 and R'_3-R'_1 of the starting resistance, lifting the relays and accelerating the motors to a still higher speed. When the current peak caused by the closing of these switches has passed, the relays drop and the cycle is automatically continued until switches *8* and *8_a* have been closed and the motors are connected across the line and running at normal speed.

The motors are reversed by throwing the master switch handle to the reverse position, when switches *1* and *3* will close, instead

.of *2* and *4*, which remain open, and the current passes from the positive line to contact S_1 on switch *1;* through the four fields in the reverse direction to S_2 on switch *3;* then through the resistances, relays and armatures to the negative line.

The relays *A* and *B* are so wound that they will respond to small variations from normal current, and are accurately adjusted for uniform load. If the motors do not possess the same inherent accelerating characteristics, i. e., if one set has a tendency to run ahead of the second and take a greater current from the line, the relay
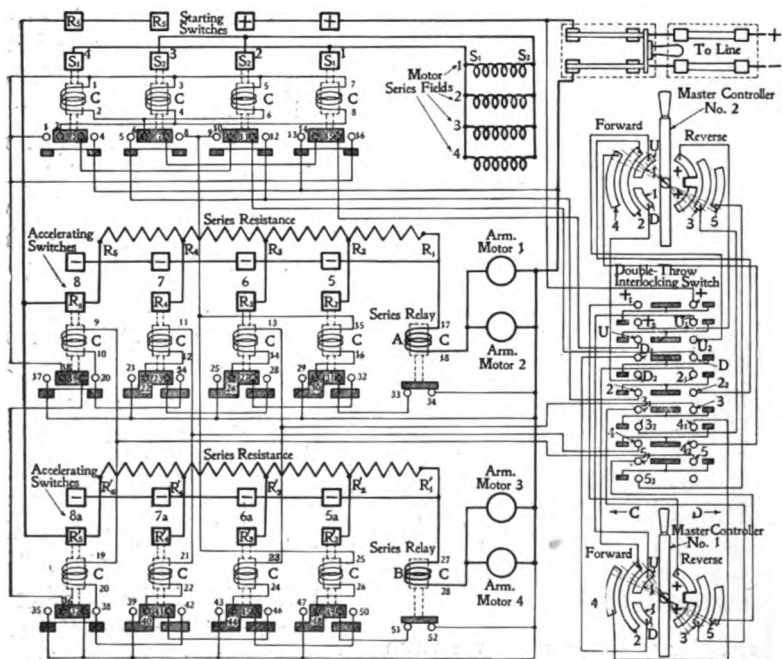

FIG. 7—DIAGRAM OF CONNECTIONS OF MOTORS OPERATING TILTING FURNACE, MASTER CONTROLLERS, DOUBLE-THROW INTERLOCKING SWITCH, AND STARTING AND REVERSING MAGNET SWITCHES.

governing the first set will lift and prevent further acceleration until the second set has had a chance to catch up, thus obviating the possibility of torsional stresses in the framework of the furnace, due to unequal operation of the two sets of tilting mechanisms. Moreover, in order to obviate any possibility of similar trouble in case the two ends of the furnace require different amounts of driving power as a result of unequal friction or mechanical imperfection, motors *1* and *3* are geared to the tilting mechanism at one end,

and motors *2* and *4* to that of the other. In this way the current through each relay is proportional to the load at both ends of the furnace so that each relay takes one-half of the total load.

With the interlocking switch set in position *D*, Fig. *7*, it will be apparent from the diagram that the operation of the control circuits from master switch No. *2* will be the same as that described in connection with master switch No. *1*. By tracing the circuit from the point of connection to the positive line, it will be seen that there is a connection to the contact on the interlocking switch marked $+$. When this is thrown to position *D*, contact is made between $+$ and $+_2$, the latter being connected with $+$ on master switch No. *2*. When the handle of master switch No. *2* is thrown to the position *5* and *U*, current passes from $+$ to *U;* thence to U_2 and *U* on the interlocking switch; from this contact to the magnet switch interlocking contacts *15-14* and *7-6;* to coils $C_{2\,1}$ and $C_{6\,5}$ on switches *4* and *2;* to interlock contacts *18* and *19* on switch *8;* to *36-37* on switch 8_a and from here to the negative line.

When magnet switches *2* and *4* close, the control circuit is set for switches *5* and 5_a, the circuit again being from the positive line, through the interlocking switch, to the master controller contacts $+$ and *2;* then back again to the interlocking switch, contacts 2_2 and *2;* to the starting switch interlock contacts *12* and *9;* to coil $C_{15\,16}$ on switch *5* and $C_{25\,26}$ on switch $5_a;$ to interlock contacts *30-31* and *48-49*, respectively, on these switches; through the relay contacts *A* and *B*, and finally to the negative line. When these switches close the control circuit is set for switches *6* and 6_a. The control circuits for the remaining switches may be traced in a similar manner, considering the master switch contacts $+$ and *4* for closing accelerating magnet switches *7* and 7_a and finally considering contacts $+$ and *5* for closing switches *8* and 8_a.

In case too heavy a current is drawn by the motors when switches *5* and 5_a are closed and the resultant peak lifts relays *A* and *B* these accelerating switches do not drop out, for the reason that with series-limit acceleration each resistance switch is provided with a transfer or holding-in circuit as follows: When magnet switch *5* is in, the circuit is changed from *30-31* and *33-34* to *30* and *29*, etc., and then to the negative line; that is, after a given accelerating magnet switch (excepting *7* and 7_a) is once closed, the accelerating relay has no further effect upon its operation until the entire operation is again repeated.

PROFITABLE DAY LOADS FOR THE CENTRAL STATION

S. A. FLETCHER

THE habit of electric living which follows the introduction of electrical devices for domestic convenience and use among the customers of electric light companies is significant, both from the point of view of the general public and that of the central station. It is a matter of education and expansion. Little by little from the use of a small amount of current for lighting for a short time in the evening to the use of current for numerous motors and heating devices, principally through the day, the advance is continued. It is notable that the average person must be shown the practical utility of the various devices offered. He is not apt to follow of his own accord the directions laid down in alluring advertisements either in a newspaper or in an attractive circular, although these may prove beyond peradventure how greatly his own interests will be furthered by acquiring and using the various conveniences which are presented. Human nature does not work this way. It requires something additional. This is shown by the rapidity with which certain electrical habits are acquired after a sample has been presented and a trial has been made. This is notably demonstrated in the case of the electric iron, in which some central stations have developed an extensive use by placing sample irons with thousands of their customers and encouraging their use on trial for a few months.

The development, during the past few years, of devices for the domestic use of electricity is one of the notable commercial advances in the electrical business. It means much for convenience and completeness of home life and, on the other hand, it has a vital importance to the central station. No intelligent person raises any question as to whether a central station should or should not have a day load, but the problem which confronts the central station manager is how to obtain the day load. The day load may be carried with practically no increase in fixed charges and only a trifling and almost inappreciable increase in operating expenses. Hence, the income from the day load goes almost entirely to increase the profit. It is therefore good business for the central station to conduct the educational campaign which will cultivate the habit of electric living and it may, on the other hand, have the satisfac-

tion of feeling that this is a truly missionary function in bringing comfort and convenience and ease to the modern home. Many of the fields of the present application of electricity in lighting and in the application of power to various industries have come about through the missionary activities of electrical pioneers who have made a common cause of the interests of the prospective customer and of themselves.

In modernizing the methods of the home and the shop, the small factory and the large industry, it is essential that attention be given not only to the characteristics of electrical devices and of the operations which they are to perform, but also to human nature as presented by the prospective customer.

The following are some of the fields, both domestic and commercial, which are particularly attractive as applications of electric current, at the same time serving to accelerate the speed of the station wattmeter during the daylight hours: ·

First there is the electric flatiron, already mentioned. These irons have been introduced with marked success in many localities. When placed in homes on trial, after first having been demonstrated, they speedily make friends, especially in hot weather. Tuesday is a particularly good day for the distribution and demonstration of irons. If the meter reader or solicitor will enquire every month or so if all the apparatus is entirely satisfactory, the central station may be kept in close touch with the consumer and opportunities will often be found for placing new labor-saving and current-consuming devices.

The sewing machine motor is an excellent means of introducing electric devices in the home. While it uses very little current, it is such a source of satisfaction to the user that it leads to the adoption of other electric devices. It also serves as a constant reminder to the business man that electric power in his factory, store or office is the best possible power for operating all sorts of machines. The introduction of these motors among dressmakers and seamstresses is particularly easy, as they find that the little motors enable them to do considerably more work in a day. The loan of one to a church sewing circle is a particularly good means of advertising.

A device which helps in the easy preparation of a meal directly on the table is the electric toaster. That type of toaster on which several kinds of cooking may be accomplished is more easily introduced than any other.

Then there are luminous radiators, shaving mugs, coffee per-

colators, silver buffing motors, washing machine motors and many more appliances which may be introduced in residences.

A recent development, which is bringing in considerable revenue to the central stations, is vacuum cleaning. Within the past year or two a great number of devices have been placed on the market for residence vacuum cleaning. The vacuum cleaning principle has certainly come to stay because the public appreciates the advantages of taking the dirt out instead of merely stirring it up. The cleaners have become so attractive to manufacturers that a small army of hand operated devices are appearing which promise to find a ready field among residences unless the central station is active in promoting the sale of motor-driven devices or at least their use by renting them to their customers at a reasonable price for the service. The motors are all operated from the lighting circuits.

The opportunities for the sale of power among manufacturers are dependent upon the community served by the central station, but there are practically no territories where some possibilities do not exist.

One application which offers a good load is the pumping of water for the city, for manufacturers or for residence service. Not infrequently special fire service mains are supplied with water from central station driven pumps, or sewage is pumped in periods of high water by special plants. Hydraulic elevators are often supplied with water from central station driven pumps. In many cases these pumps may be controlled automatically by special float or pressure regulators which will eliminate all special attendance of an engineer.

The development of the day load may be carried on very readily among blacksmiths and others who require forge fires, as electrically driven blowers furnish a better supply of air than is possible by hand. The load is not large, but is on practically all day.

A similar steady load which lasts all day is furnished by cash carriers in department and other stores, where small motors operate the carrier systems directly or by an air compressor and pneumatic tubes. A moderate sized store of several departments on one floor would take about a quarter or half horse-power motor.

A particularly good load in the summer months, when the consumption for light is decreased, is furnished by electrically operated refrigerating machines. These are used by druggists, grocers, butch-

ers, cafes, restaurants, hotels, and in large residences. The compressors operate either 24 hours or ten hours per day. If desired, special arrangements may be made to keep the load off the peak. The size of motor required varies according to the amount of space to be cooled and the length of time the compressor is to be run. For a 500-pound refrigeration set to be run 24 hours and produce the equivalent of melting 500 pounds of ice, a one or one and one-half horse-power motor would be used. If the same amount of refrigeration were to be obtained by running one-half the time, a larger compressor would be required with a two horse-power motor. Such a compressor would maintain a room 8 by 10 by 10 feet at a temperature of approximately 40 degrees F. There is a distinct economy in using these machines except in the smallest sizes. But in all cases the elimination of the dirt and general nuisance connected with the supply of ice proves a strong factor in effecting the sale of this type of apparatus.

General machine and repair shops offer an excellent field for the sale of power, as the application of motors to machine tools, if properly made, increases the productive capacity of the tools. If an inexpensive installation is desired, the group system of drive is employed and the line shafts already installed driven by motors. It is preferable to reduce the lengths of the longer shafts and thereby reduce the friction loss. For some of the tools individual adjustable speed motors are far preferable, as for lathes, drills, boring mills and others, so that direct-current motors are necessary. For group drive the squirrel cage induction motor is entirely satisfactory. The connection of an individual motor to each machine tool is the method recommended for new installations as it permits the location of the machines wherever the manufacturing sequence requires without reference to the power supply. This permits of the utilization of space otherwise wasted and reduces the handling of material to the minimum.

Ventilating and exhaust fans are being more and more demanded for all places where people congregate, as in schools, halls, theaters, churches, as well as in factories where fumes and smoke are present, and in other places where the air needs constant renewing. These ventilating fans run often as much as ten hours each day. The size of motor required is dependent upon the amount of air to be handled and can be easily obtained from any manufacturer of fans. Shunt motors or squirrel-cage induction motors are ordinarily employed.

In every central station territory one or more printing estab-
lishments may be found where motors can be installed to drive
printing presses, job presses, stitchers, punches, etc. The conven-
ience of electric motor drive is one of the most important reasons
for equipping such plants electrically as each press may be entirely
independent of all others and this is impossible with mechanical
drive. The individual motor system is used exclusively on all up-to-
date installations in preference to group drive. If direct-current is
available shunt and compound motors are used, the latter where
the starting conditions are severe or where the motor is liable to
sudden overloads as in a paper shear. Alternating-current motors
are used frequently with wound secondaries to obtain different
speeds for various classes of work. Direct-current motors with
armature and field control are also used. The use of glue pots,
electrically heated bookbinders' tools, metal heaters for monotype
and linotype machines, and a number of other heating devices adds
materially to the day load of the station. One of the latest devices
in a minute and forty-five seconds under an almost instant heat of
300 degrees, which may be raised to 500 or even 600 degrees in
emergency. It formerly took from 12 to 24 minutes for this opera-
tion. In this case the saving in time in getting out a big newspaper
makes the electric drier a very valuable feature regardless of ex-
pense.

Few communities are without a planing mill or some sort of
woodworking establishment for the preparation of material for
carpenters, building contractors, etc. These plants are good pros-
pects for electrical power from the central station, although the
load may be rather irregular. In a new plant a considerable reduc-
tion in the investment is effected by buying power; in an old plant
it frequently happens that electric power may be put in when some
change becomes necessary, such as the replacement of a boiler or
an engine, or the addition of a new machine which would overload
the engine. The refuse may frequently be baled or sold for nearly
as much as the cost for power. Low pressure boilers are used for
the kilns and for heat in the winter, and if desired the refuse may
be burned for these months. Frequently the cost of electric power
will be less than the wages formerly paid to an engineer to run the
steam plant. If the plant uses shaving collectors the load will be a
particularly profitable one for the central station, as the blowers
run steadily all day long. Auxiliaries in the shape of electrically

heated glue pots are often overlooked in woodworking plants. It is a steady load for practically the full day.

The only motors which are ordinarily considered for woodworking plants are the short-circuited secondary induction type. For some machines with large starting torque the wound secondary type of motor is used. An occasional installation is made using shunt and compound-wound direct-current motors, but in these cases it is necessary to enclose the motors to keep out dust and shavings.

There are a great many more applications of a general nature, such as coffee grinders, meat grinders for grocers and butchers, adding machines for banks, mercantile establishments, horse groomers for livery and other stables, small air compressors and pumps for druggists and doctors, which may be secured if a little time is spent in studying the requirements of the individual cases.

There are many industries which are of a more or less special nature so that a central station may have but one in the entire territory in which case the advice and assistance of motor manufacturers may be employed very successfully as their experience covers a very wide territory and puts them in a position to advise on motor applications of every description.

EXPERIENCE ON THE ROAD

PARALLELING DIRECT-CURRENT GENERATORS

SOME time ago the writer was called to an isolated plant to find out why two direct-current generators would not run in multiple. The machines were both of 75 kw capacity direct-connected to high speed automatic engines and had been in service some time and had been regularly operated in parallel on the same bus-bars. The plant, located in a small theater building, was in charge of a very inferior engineer and had no proper switchboard or meters. On questioning the engineer nothing could be learned except that the machines would run perfectly and deliver normal output separately but would not run in parallel. The engineer insisted that nothing unusual had happened and, as is usually the case, remarked that No. 2 machine never was any good and was the one that made the trouble. The plant was not ordinarily run during the daytime, such light as was needed being furnished by connecting the city lighting circuit to the bus-bars. As the engine room was lighted by open arc lamps, it occurred to the writer that some data could be obtained and conclusions drawn without "Mr. Engineer" being any the wiser. One machine was started and connected to the bus-bars. The station arc circuit was then connected to the bus-bars and it was observed that the crater of the arc in a nearby lamp, which could be observed, was in the proper carbon, the light being thrown downward. The machine was then disconnected and the second machine connected to the bus-bars and lights in the same way, when it was noticed that the crater was reversed. It was thus evident that the second machine had been reversed, although it was difficult to account for this. Both machines were now running and No. 1 was again connected to its load. The armature leads of No. 2 were disconnected and a "testing circuit" of lamp cord was connected to its field to reverse the polarity which had first been tried privately with pocket compass. The armature leads were then reconnected and No. 2 was tried again on the arc circuit, now showing proper polarity. The engineer was all this time airing his grievances against this No. 2 machine as having weak insulation, sparking, taking extra steam, etc., etc. Without informing him that anything had been done to correct matters, he was met with a flat statement that the machine was all right and that the two machines would run together and

before he had fully recovered his breath they were doing so, having been quietly switched together by the writer. The entire absence of any voltmeters or ammeters prevented any investigation of the reasons for this reversal of field.

The machines were shut down and the city lighting circuit thrown on. The arc light was then observed to burn reversed.

The engineer was already in a somewhat penitent frame of mind and became absolutely tame when told that the whole trouble was due to his carelessness in throwing city power on the bus-bars without disconnecting No. 2 machine. As he already had a guilty conscience in regard to such an incident this proved the final straw. Further, he was informed that a suitable switchboard would have prevented such an incident and that a voltmeter would have at once indicated the reversed polarity. The result of this incident was that an order was placed for an up-to-date switchboard.

MEETING EMERGENCIES

C. R. DOOLEY

WHILE it is never a practice to be recommended, it sometimes appears to be necessary to operate 125 volt direct-current motors from 550 volt circuits. Such an arrangement was recently used where it was desired to operate an air pump and only a 125 volt motor and a 500 volt circuit were available. The air pump was used to maintain an air pressure of about 25 lbs. per square inch, and hence it was very desirable that the operation of the motor be made automatic so that it would start up and run as long as was necessary to keep up the pressure and then be stopped until the pressure dropped. An automatic switch was arranged so that it would close the motor circuit when the air pressure dropped below 20 lbs. and would open the circuit when the pressure reached 30 lbs. The check valve was only about ten feet from the pump and thus the motor was required to exert nearly full-load torque at start.

In order to determine the resistance required to operate the motor on the higher voltage the motor was taken to a place where it could be operated under its normal load from a 125 volt circuit, and readinge were taken of the field current and armature current by placing meters temporarily in the circuit. With this information it was a simple matter to determine that approximately normal current would flow when the motor was placed on the 500 volt circuit

with a resistance of 100 ohms in the armature circuit and 500 ohms in the field circuit.

These resistances were procured and placed in position and the motor started and apparently everything was satisfactory. The following, however, illustrates in a general way the sort of unexpected trouble that the electrician is continually meeting. The expert of long experience will avoid many troubles through his superior knowledge, but such knowledge cannot be acquired in a day nor can it be secured from text books. The motor started and apparently was running as well as could be expected. When full pressure in the reservoir was reached, the automatic cut-out switch operated, but the current continued to flow across the one-half inch switch gap with a burning arc. It was then seen that a switch suitable for 125 volts would not work on a 500 volt circuit. It was suggested that a relay be used or that the switch be remodeled so that it would open with a larger gap. This would have involved complete re-design. Finally a simple series blow-out coil was arranged by mounting an electro-magnet, obtained from the ruins of an old arc lamp, near the switch gap.

Operation for a short time revealed the fact that, with the resistance connected in series with the armature, the motor would not give sufficient initial torque to start the air compressor against the twenty pounds pressure in the supply pipe, especially if the piston of the pump had stopped at the beginning of the pressure stroke. In other words, the resistance which had been inserted in the armature circuit was too great to allow sufficient armature current to flow. This resistance was reduced until the motor would start, but with this combination the motor attained an excessive speed and, moreover, the current necessary to start the outfit was so large that there was danger of overheating the armature resistance box. The first decision was that a new and larger resistance box be obtained, which would have meant discarding the first one, costing approximately eight dollars, and purchasing another at perhaps twice the cost. It was also suggested that a smaller pulley be used on the motor shaft but this would have resulted in reduced operating speed, though it might possibly have permitted the motor to start the pump under load. However, the pulley in use was only two inches in diameter so that it was a question whether the belt would cling to a smaller pulley. As is usual, the simplest and best remedy was thought of last of all.

The difficulty was avoided rather than remedied. A relief valve was inserted in the air pipe between the pump and the check valve, the stem of the relief valve being connected to the armature of an electro-magnet—(here again the ruins of an arc lamp furnished the necessary magnet parts). The magnet was mounted on the wall directly over the valve. The magnet coils, which were wound with heavy wire, were connected in series with the motor armature and switch blow-out coil. It was an easy matter to arrange this apparatus so that the valve would be closed when the magnet was energized but otherwise would remain open. The operation of the whole apparatus was then as follows: As soon as the full pressure is reached, the automatic switch cuts out; the relief valve opens, since the retaining magnet is no longer acting; the check valve prevents the air in the reservoir from escaping, and the pump, together with about ten feet of pipe between the pump and the check valve, is entirely relieved of back pressure. When the pressure in the reservoir falls to 20 pounds, the automatic switch closes, and allows current to flow which closes the relief valve, and the pump starts under practically no load. The capacity of the pipe from the pump to the check valve was sufficient to allow the motor to attain its speed.

Sometime after the equipment was started the automatic switch was almost totally destroyed. At first it seemed certain that some one had been tampering with it, as the damage was done when no one in charge was about the place. Close examination revealed the fact that there was a ground on the line. The bracket supporting the automatic switch was necessarily grounded through the air pipe, to which it was attached through the connection to the controlling diaphragm. The nose of the blow-out coil had worn through its taped insulation so that it had come in contact with the switch bracket and therefore was grounded, hence the accident. The switch was repaired and insulated from the air pipe by placing an insulated gas pipe coupling in the pipe line just below the controlling diaphragm after which satisfactory operation was resumed.

THE JOURNAL QUESTION BOX

264—EFFECT OF SHORT-CIRCUIT ON SEPARATELY EXCITED FIELD OF ALTERNATOR—If a short-circuit occurs on a line to which power is supplied by an alternator, the field of which is separately excited from a shunt generator, what reaction will occur in the alternator field?

A. F. E.

The self-induction of the alternator will limit its current to about two or three times the full load value, but the power-factor will be low. This means that a short-circuit will produce sudden and strong demagnetization of the field, which will result, through transformer action, in a corresponding sudden rise in the field current, regardless of the ordinary source of supply of the field excitation. See also No. 155 in the Oct., '08, issue. H. M. S.

265—POWER-FACTOR—The armature of an alternator is hotter than the field when the power-factor of the load is high. The field is hotter than the armature when the power-factor is low. Assuming constant load with these two conditions, what is the explanation? What is the explanation when light or heavy load is the cause of low or high power-factor in the case of induction motors?

A. F. E.

If by constant load is meant a constant k. v. a. output (*i. e.*, both the voltage and amperage remaining the same), an explanation will be found in No. 142 in the JOURNAL for September, '08. If constant kw. is meant, the lower power-factor will mean more armature current, and, therefore, more armature heating. It would be inferred, however, from the comparative temperatures of armature and field given, that constant current output is meant and not constant power, the percent rise in temperature with decrease in power-factor, being due to the extra excitation necessary to overcome the demagnetizing effect of the lagging (wattless) component of the current. In the case of induction motor load the wattless component is largely magnetizing current for the motors, and is practically constant for all loads, although the power-factor decreases as the working current is lowered. The demagnetizing effect of this lagging component will, therefore, remain constant, and the only increase in field current required with increase of load will be that needed to force the required working current through the impedance of the generator, line and motors. In connection with the subject of Power-Factor refer to Nos. 78, 126-129 inclusive, and 165.

H. M. S.

266—POWER-FACTOR—(a)—In case of alternating currents supplying inductive loads, does the exciting current flow in phase with the e. m. f.? (b)—In case of parallel circuits having different inductances, is the current in each circuit apt to have a different angle of lag? (c)—Why is it that by changing the excitation of a synchronous motor the power-factor of the generator is made to lag or lead? How does the field flux change the power-factor? J. D.

(a) The exciting current does not flow in phase with the e. m. f. This explains the low power-factor of an induction motor connected to a line and running without a load. Under such conditions the current drawn from the line is practically all excit-

ing current. (b) — Yes. (c) — The voltage is fixed by that of the line. The speed is fixed by the frequency of the circuit, therefore, the net excitation is fixed. The lagging component of the current demagnetizes the field, and, hence, the stronger the field the greater the lag, relative to the counter-e.m.f. of the motor, or lead, relative to the generator e. m. f. In a corresponding manner, a decrease in field strength of the motor requires the leading component of the current to supply the discrepancy and keep the net excitation constant. See the following articles in the JOURNAL: "Synchronous Motors for Improving Power-Factor," and editorial, Aug., 1907, p. 425; also "A Graphic Calculator" and editorial, Nov., 1907, p. 627. Refer also to No. 265. H. M. S.

267—TRANSMISSION LINE LOSSES— With two three-phase 6 600-volt transmission circuits, transmitting 250 kw over a distance of 12 miles, how much greater will be the inductive loss with the three lines of the circuit arranged in the form of a 24-in. equilateral triangle, and arranged in one plane on a single cross arm carrying four insulators, it being proposed to run the three lines on insulators 1, 2 and 4 for five spans and on insulators 1, 3 and 4 on the next five spans, etc., so that the distance between the middle wire and the two outside wires will, on the average, be equal. Insulators 1 and 2, and also 3 and 4, are 20 in. apart, and insulators 2 and 3 are 18-in. apart. There is a complete transposition of the three wires at four equidistant points upon the line. E. B. N.

With the wires on a single cross arm, the loss will be about ten percent greater than with the three wires at the vertices of an equilateral triangle. The inductive loss with the triangular arrangement is calculated as follows: If equal currents are carried in the three wires A, B and C, the induced e. m. f. in any one of the three phases such, for example, as BC, is made up of two components, viz., that due to current in B and that due to cur-

rent in C. As B and C are symetrically located with respect to A there is no e.m.f. induced by the current in A. The e. m. f. due to current in B at 25 cycles is approximately 0.0096 $\log \dfrac{d}{0.78r}$ volts per ampere per 1,000 ft. of line, where d is the distance between B and C, or 24 inches, and r is the radius of the wire.

In order to get numerical values for the inductive loss by the two methods of transmission it is necessary to assume the size of wire and the frequency. Assume a circuit as shown in Fig. 267 (a) with the wires arranged in a triangle of 24 in. to the
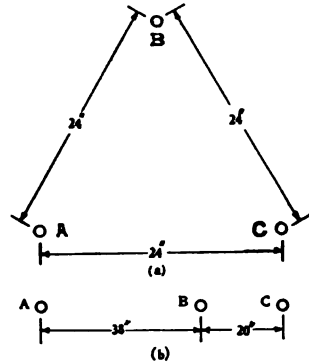

FIG. 267 (a) AND (b)

side. Assuming the wires to be No. 4, B. & S. (0.204-inch. in diameter), the transmission of 250 kw at 100 percent power-factor will give a current of approximately 22 amperes per wire.

At 25 cycles the inductive drop or loss in any phase such as AC, Fig. 267 (a) is made up of three components, viz., those due to current in each of the three wires. As B is equidistant from A and C the component of induced e.m.f. in AC due to current in B is zero. The component due to current in A is equal to $0.0096 \log \dfrac{d}{0.78r}$ or 0.102 volts per 1,000 ft. per ampere, where d is the distance between the wires A and C, or 24 in. and r is the radius of A in inches. The component due to current in B is of the same numerical value but is 60 degrees out of phase with that due to

current in A. The vector sum of these two values is at right angles to the e. m. f. between A and C, and is, therefore, the inductive drop. The formula is given for natural logarithms as follows: $0.0096 \log \dfrac{24}{0.78 \times 0.102}$

$= 0.0548$ volts per 1 000 ft. per ampere

$=$ induced e.m.f. due to A or C. The total due to both A and $C = 1.73 \times 0.0548 = 0.095 =$ inductive loss per ampere per 1 000 ft. or 132 volts for 22 amperes, 12 miles.

If the wires are located as in Fig. 267 (b) on the same cross-arm there will be different induced voltages in the three phases unless transpositions are made. In AC the induced voltage will be as follows: Due to current in $A = 0.0096 \log \dfrac{58}{0.78 \times 0.102}$.

due to current in $B = 0.0096 \log \dfrac{38}{20}$

due to current in $C = 0.0096 \log \dfrac{58}{0.78 \times 0.102}$. That part due to current in B will be cancelled because of the fact that the arrangement shown in Fig. 267 (b) holds for only one-half the distance, while for the other half B is 20 in. from A and 38 in. from C.

Assuming first no transpositions except the shifting of the position of B, the e. m. f. induced in AC is the vector sum of the e. m. f.'s due to A and to C which are 60 degrees apart in phase. Then $1.73 \times 0.0096 \log \dfrac{58}{0.78 \times 0.102} = 0.11 =$ induced volts per 1,000 ft. per ampere.

In AB the induced voltage is:

1—Due to A first half distance $=$
$$\frac{0.0096}{2} \log \frac{38}{0.78 \times 0.102}$$

2—Due to A second half distance $=$
$$\frac{0.0096}{2} \log \frac{20}{0.78 \times 0.102}$$

3—Due to B first half distance $=$
$$\frac{0.0096}{2} \log \frac{38}{0.78 \times 0.102}$$

4—Due to B second half distance $=$
$$\frac{0.0096}{2} \log \frac{20}{0.78 \times 0.102}$$

5—Due to C first half distance $=$
$$\frac{0.0096}{2} \log \frac{58}{20}$$

6—Due to C second half distance $=$
$$\frac{0.0096}{2} \log \frac{58}{38}$$

The phase relations are such that *1* and *2* are at 60 degrees angle from *3* and *4*, and *5* and *6* are at right angles to the resultant of the first four. The vector sum of the above is 0.0975 volts per 1,000 ft. per ampere. *With transpositions* the e. m. f. in each phase will be the average of the values found above for *AB* and *AC*, or 0.104 volts per ampere per thousand feet. For 12 miles and 22 amperes per wire the induced e. m. f., or inductive loss is 145 volts. This, then, is about ten percent greater than the loss with the wires arranged in a triangle.

This method will be seen to be an application of the principles outlined in articles in the JOURNAL for Dec., '05, p. 713; June, '06, and Aug., 06, pp. 334 and 437, respectively.

<div align="right">A. W. C.</div>

268—OIL IMMERSED CONDENSER FOR TESLA COIL—In constructing an oil immersed condenser for use with a 4 kw, 40 000 volt, 60-cycle, transformer and induction coil, what margin and thickness should be used for the glass or mica dielectric; and what size of sheet copper plates to give a total of 160 or 180 square inches on the plates?

<div align="right">M. L. E.</div>

We judge from your statement that you are expecting to use a condenser composed of alternate plates connected in multiple to apply to an induction coil circuit as represented in Fig. 268 (a) or Fig. 268 (b); the source of power in either case being an alternating-current transformer. Fig. 268 (a) represents a method of connection using a mechanical interrupter, consisting of a toothed wheel revolved at a rapid rate, alternately making and breaking the circuit. Condenser A is so made that the capacity can be adjusted by increasing or decreasing the number of plates in order to obtain a condition of resonance, *i. e.*, tuning to give a high frequency discharge across the spark gap to which the secondary or high-tension terminals of the coil are connected. With the connections represented in Fig. 268 (b) the high

frequency oscillations are obtained by tuning the circuit containing the secondary of transformer No. 1, condenser *A*, and spark gap *S*. With a condition of resonance in this circuit, the circuit connecting to condenser *B* is also adjusted by increasing or decreasing the capacity of condenser *B* until the condition of maximum discharge is obtained across the spark gap to which the secondary of the induction coil is connected. In either case it will be seen that it is necessary to obtain a proper condition of resonance by adjustment of the condenser capacity, in short, by what is known as "tun-

(a)

(b)
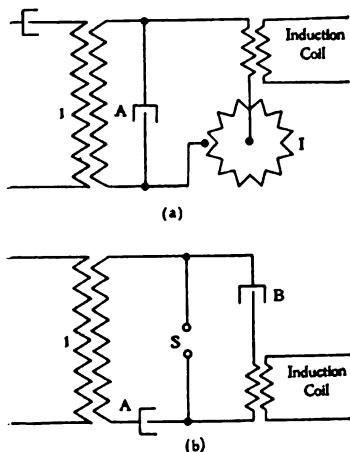
FIG. 268 (a) AND (b)

ing." It is therefore impossible to state definitely regarding the proper number of plates to be used; this must be determined by experiment. To obtain the total area of plates, equal, for example, to 180 sq. in., any convenient size of plate may be chosen, *e. g.*, ten plates 3 by 6 inches could be used; or, two plates 9 by 10 inches would give the same total area. If it is desired to use glass plates for the dielectric, care should be taken to select glass that is clear and free from flaws. Glass of approximately one-fourth inch thickness would probably be found to be sufficient to withstand the potential of 40 000 volts. Mica of about one-half the thickness would give the equivalent in dielectric strength and

would have the advantage of increasing the capacity for a given area of plates because of the corresponding decrease in distance between copper plates. The margin, measured over the surface of the dielectric from the edge of one copper plate to the other, should be from eight to ten inches, *i. e.*, four or five inches from copper plate to the edge of the dielectric. The margin on the side at which the terminals from the copper plate is brought out should be twice that on the other sides in order to insure against breakdown at this point.   S. M. K. AND A. B. R.

269—COMPENSATOR FOR ARC LAMP— In connection with the design of an auto-transformer with laminated core to be used as a means of regulating the voltage and current of an arc lamp, I wish to obtain a formula for calculating the inductance of such a coil. The reactance is, of course, equal to $2\pi nL$, but how is L derived? The transformer will be used on a 110-volt, 60-cycle circuit. Please designate where to make the taps on the coil necessary to secure 15, 22, 29, 36, 43, 52 and 60 amperes respectively.   H. J. W.

It is evident that what is desired is to compute the current drawn from the line by an arc lamp operated from an auto-transformer, by calculating the impedance of the transformer. However, the reactance of an auto-transformer is not a function of the total number of turns but follows a complex formula involving the number of turns on each side of the tap used, the dimensions of the iron core, the arrangement of the coils, the space between coils, etc., too long to be fully explained in the Question Box. It may be stated, however, that for an auto-transformer of the size required, five percent will be a fair value for the impedance. This means that when the arc lamp carbons are brought together, thereby short-circuiting part of the auto-transformer, the current will rise to 100 percent ÷ 5 percent or 20 times the full-load value. The voltage which will be impressed on the arc will bear the

same ratio to the line voltage as the number of turns included between the taps to the lamp bears to the total number of turns. It is impossible to say what current is produced by a given voltage through an arc, as this will depend on the length of arc, the amount of the resistance in series with the arc (ballast), etc. The best scheme probably would be to bring out several taps between 40 and 60 volts and then select the proper one by trial.   A. P. B.

270—ALTERNATING AND DIRECT-CURRENT SOLENOIDS — Please give a formula for obtaining the attractive force in lbs. exerted between the winding and core of a solenoid with an iron core of given length and diameter; the current flowing in the winding, the number of turns in the coil, the frequency, the relative position of the core and all the other dimensions and conditions being known. I have consulted many text books, but can find no principle directly applicable to this case. Will the force exerted be different if the solenoid is operated on direct-current instead of alternating current?   E. P. N.

Alternating-current solenoids differ radically from direct-current in that in the former the flux or number of lines of force is not at all dependent on the length of gap or other conditions of the circuit but only on the number of turns in the coil, the frequency, and the voltage impressed on the coil terminals. Since, for ordinary cases, these are constant in a given case, it follows that the flux will be constant throughout the range of the magnet, *i. e.*, as the magnet pulls up, the flux and pull will not increase as in a direct-current solenoid. In the latter, the current flowing will depend only on the resistance of the coil and, neglecting the effect of heating in changing the resistance of the coil, the current will remain constant. In an alternating-current magnet, however, the current is very heavy at the beginning of the stroke when the magnetic circuit is open, and is choked down when the magnetic circuit closes and the core pulls in. In an alternating-current magnet, therefore, the position of the core does not effect the pull but governs the heating, while on direct-current the opposite is the case. The total flux in an alternating-current magnet is equal to E×$10^{-8} \div 4.44$ fN, where $E =$ Volts at terminals, $f =$ frequency, and $N =$ number of turns on the coil. Now if the area of the core$=A$, then E×$10^{-8} \div 4.44$ fN. $= B$, and the pull in lbs. $= AB^2 \div 72\,134\,000$. In practice a magnet without a return circuit for the magnetic flux would not prove practical; alternating-current
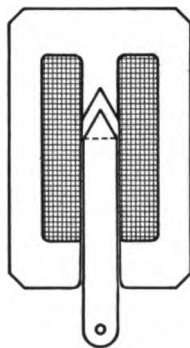

FIG. 270 (a)

solenoids are usually made with a laminated circuit to reduce eddy currents, and in all solenoids for pulling purposes it is best to make a return circuit as shown in Fig. 270 (a), the plunger also being laminated, except in case of small capacity; for these, cast iron offers sufficient resistance to the eddy currents to prevent serious overheating. A single-phase magnet is apt to be quite noisy and, accordingly, various patented schemes are used to reduce this trouble; it is practically impossible, however, to eliminate it completely. For further information on this subject see various handbooks for electrical engineers.   F. W. H. AND E. F. L.

NOTE

In the article on "Meter and Relay Connections" in the JOURNAL for May, 1909, the following two lines were omitted and should be inserted between the first and second lines, p. 305:—"circuit 90 degrees, the wattmeters have been made in indicate wattless volt-amperes instead of true watts. This is accomplished on the."

Condensers for Steam Power Plants The literature of the power plant and of the various elements which enter into the make-up of a plant, is fairly extensive, and has treated in an exhaustive manner nearly all of the principal elements which are found in plants of modern design. While, of course, the last word has not been said on the design and operation of the boilers, or even on the theoretical and practical phases of the design and operation of prime movers, there is ample information at hand to enable the power plant engineer to select with certainty the best apparatus for the conditions which he has to meet. This is also true, though to a less extent, of the literature concerning the auxiliary apparatus whuch is a necessary part of every power plant. By reference to the various indexes of engineering publications, numerous articles will be found bearing upon the problem of feed water heating by open and closed heaters, of the use of economizers, of the relative efficiency of natural and mechanical draft and the like. Unfortunately, the design and operation of condensers have not received their fair proportion of discussion. The lack of literature available for reference by the engineer who is making a choice of condensers for a particular location is doubly unfortunate for the reason that while the condenser is a simple piece of mechanism and performs a simple thermal function, the problem of obtaining high vacua is by no means easy of solution. Troubles often arise with the condenser system where they are least looked for, with the very common result that while a system may be designed for, say, a 28-inch vacuum, not more than 26 or 27 inches are actually obtained in practice. Further than this, the use of large volumes of cooling water of an inferior grade subjects the system to rapid deterioration by corrosion, which must be guarded against in the choice and arrangement of the condenser, if failures and shut-downs are to be avoided.

The JOURNAL is fortunate in being able to present to its readers the contribution appearing in this number by Mr. Francis Hodgkinson on "The Choice of a Condenser." Although written by a scientific designing engineer, the article is not in the nature of a scientific

treatise. It is by far the best article bearing on the subject which has appeared recently. It should be of great assistance to power plant engineers in deciding on the best type of apparatus for any given plant.

Among other features of the article, the surface condenser, which some years ago was more largely recommended than at present, is shown to be both theoretically and practically the inferior of the jet condenser, except under certain conditions where the necessity of returning the condensate to the boiler feed system outweighs other considerations, and where the power required for its operation must be reduced to a minimum. Except for these special conditions, it is probable that as time goes on the surface condenser will be even less in favor than at present.

In the discussion of the jet condenser a distinction is drawn between the plain jet condenser and the barometric and ejector types. It is a common error to use the word "jet" condenser as synonymous with "barometric" condenser. One often sees the statement in the technical periodicals that a "jet or barometric condenser was used."

While it is not so stated in Mr. Hodgkinson's article, it would appear that, all things considered, the centrifugal jet condenser has, for the average installation, the greatest number of points in its favor. The long exhaust pipe which not infrequently is a necessity with the barometric condenser has disadvantages which must be reckoned with but which may be guarded against in laying out the plant. The barometric type has the advantage that the circulating pump handles the cooling water on its way *to* the condenser and before it is heated by the condensed steam, which is an important factor in reducing the inevitable wear and corrosion of the circulating pump, which in the other case, handles hot water, particularly if the pump is of the centrifugal type.

Incidentally, Mr. Hodgkinson's article gives a very interesting review of air pump design and states in a concise manner a great many things which power plant engineers should know. The proper place of the economizer in the boiler feed system is also touched upon and emphasis is laid upon the undesirability of omitting some form of feed water heater and utilizing the economizer as both a heater and a purifier. The open heater is an excellent dumping ground for those impurities in feed water which are released at ordinary temperatures of hot feed, while the economizer is a very poor place for this deposit to accumulate owing to the difficulty in

keeping the tubes clean. For this reason the economizer is not a substitute for, but rather an auxiliary to, the feed water heater. And, as further pointed out, its greatest usefulness is realized in those cases where mechanical draft can properly be installed.

R. A. SMART

Development of Small Transformers
Mr. Reed's paper on "Distributing Transformers" deals with a hackneyed subject in an interesting way. The small transformer is one of the simplest and most common kinds of electrical apparatus. It has undergone a panoramic series of improvements resulting in new transformers almost annually for a score of years. Simple as it is, there is scarcely another piece of apparatus which has a greater variety of conditions to meet. In design it is dependent upon the properties of materials and methods of construction. In performance it must be a compromise between first cost and the requirements of operating companies. Its mechanical construction and mounting are determined by various matters of convenience in installation and handling. A change in any one of these important factors is apt to lead to important modifications. For example, the introduction of oil as an insulating and cooling medium and the recent improvements in transformer steel have led to important changes in design.

One of the especially interesting points in Mr. Reed's paper is the analysis of cost, in which it is shown that too great attention to low hysteresis loss may lead one to overlook the losses resulting from the exciting current which may in certain cases considerably exceed the hysteresis loss.

Another feature of special interest is the curves of temperature rise showing the method of determining from one test curve the rise of temperature under other conditions of load and time. There are probably but few, even among those already well informed upon the subject, who will not find points both of novelty and interest in Mr. Reed's paper.

The Journal Question Box
Since The Journal Question Box was started a year and a half ago, there have been received and answered four hundred and twenty-five questions, most of which have been published. The questions not yet published have either been crowded out owing to lack of space, or have not been of general interest and have been given a personal reply. It is interesting to find that the

inquiries have come from some thirty states, and from a number of foreign countries, such as Australia, Canada, England, Hawaii, Japan and Mexico. Numerous questions have been received with the urgent plea for haste in securing a reply, as the questioner wished to make a direct, practical application of the answer. In fact, a distinctive feature of this department in the Journal has been that the questions indicate that their authors are attempting to secure the solution of real difficulties in their every-day work rather than of academic perplexities.

The JOURNAL has always aimed to be of practical assistance to its readers and the Question Box furnishes an additional means of keeping in personal touch with the wants of its subscribers. An excellent method of co-operation has been adopted by some of the more prominent libraries, by which they assist individuals or companies in search of information by securing the necessary references. The systematic and thorough methods in effect in these libraries are of great value in securing published data. But a large part of the information which is furnished by The Journal Question Box is not to be found in books; first, because there are very few books furnishing similar information, and second, because many of the replies relate to subjects in which changes and improvements are continually being made. Moreover, many replies are obtained from or approved by engineers who are constantly in touch with the latest developments in electrical and mechanical engineering, and are specialists on the questions involved, and hence the replies are several years ahead of regularly published books obtainable at libraries. Some questions are of such a nature as to be answerable only by an expression of preference based on experience. In such cases the answers are open to discussion, and comments, either at variance with, or in corroboration of, replies which have been published, are gladly received and given due consideration.

This department has proven to be an excellent source of suggestions for future articles. For example, when a large number of questions are received indicating a desire for information on certain topics, advantage may be taken of these suggestions, resulting in the publication of articles or a series of articles taking up the subjects in question more in detail than is possible in the limited space assigned to the Question Box. For instance, a number of questions have been received, which indicate that there is a considerable demand for a simple and practical method of determining the proper connections of three-phase wattmeters regardless of the power-fac-

tor of the circuit whose power is to be measured. In view of this, the contribution by Mr. M. H. Rodda, in this issue of the JOURNAL should be of special interest.

Furthermore, the questions and answers have repeatedly demonstrated the value of many articles which have appeared in the earlier issues of the JOURNAL, as many of the newer subscribers, who have not all these copies at hand, have been enabled to obtain very complete replies by securing single issues or complete back volumes.

What Grades Mean in Electric Traction

It is generally understood that an electric car can run on any kind of a track, no matter how many grades and curves there may be, and there are certainly good grounds for this belief. The manner in which steep hills and sharp curves are negotiated by electric cars is certainly little less than marvelous. This class of performance has become so familiar to us that we seldom stop to consider what is involved.

There is one very peculiar circumstance in connection with operating vehicles of any kind over a hilly road. There is not necessarily any extra expenditure of energy in propelling the vehicle up the grades, as the energy thus employed is only converted to another form; that is, the weight of the vehicle has been raised a certain number of feet, and represents just so many foot-pounds. This energy would not be again converted if the vehicle did not go down grade and in so doing use this energy. In going down grade, it may be used in overcoming resistance through motion of the vehicle within the limits of its ordinary speed, or absorbed by the friction of the brakes in preventing excessive speed. From this it is evident that where the down grades are not sufficient to cause the vehicle to exceed its safe limit, the grades may be neglected in calculations of power consumption. The amount of grade required to cause a car to attain a certain speed depends upon the condition of the track, the frictional resistances and the head resistance due to the air. All of these factors vary to some extent under different conditions. Under good operating conditions of track a single car, weighing 50 or 60 tons, will attain a speed of about 60 miles per hour on a grade of one percent, without other propelling power than that due to gravity. A train of eight or ten such cars, under the same conditions, will attain a speed of 90 or 100 miles per hour. The reason for this

difference in speed is that the air resistance is much greater on the front car than on a trailing car. The head resistance increases rapidly with the speed and is very small at slow speeds. On the other hand, the frictional resistances are nearly constant, decreasing slightly as the speed increases. At slow speeds, the frictional and the rolling resistance of the wheels on the rails ordinarily amount to about six pounds per ton; that is, at a speed of, say, five miles per hour, there will be required six pounds pull at the draw-bar, for every ton of weight, to keep the car in motion. From this it follows that a car or a train of cars will move at about five miles per hour on a grade of three-tenths of one percent.

Now, if single cars are operated at speeds between five and sixty miles per hour, grades of from three-tenths to one percent, depending upon the average speed, may be neglected from a power consumption stand-point. Grades greater than those that will give these average operating speeds, increase the power consumption by exactly the amount required to lift the weight of the car up the grade. This is modified to some extent where the grades are very short. Thus for speeds averaging 30 to 40 miles per hour, grades greater than one-half of one percent must be taken into consideration when determining power consumption. As at moderate car speeds the resistance to motion is only ten or twelve pounds per ton, grades of two or three percent mean many times the power expenditure that will be required for operation on a level.

As the usual grades on steam railroads are very much less than on so-called trolley roads, the power consumption for a given service is very much less. In cases where steam railroad are converted into electric roals, the motor equipment of the cars shows up to a very much better advantage in point of total weight of equipment and power consumption than on ordinary trolley roads.

WILLIAM COOPER

THE CHOICE OF A CONDENSER

FRANCIS HODGKINSON

NOW that steam turbines demanding high vacuum appara-
tus are being employed in all modern plants, the ques-
tion is often asked, what is the best kind of a condenser
to use? As a matter of fact, the prime mover has scarcely anything
to do with the selection. The considerations which most govern
the choice of a condenser depend upon such things as the follow-
ing:—

Purity of the cooling water available.

Elevation and location of the cooling water with reference to
the power plant.

Rise and fall of tides and floods.

Quality and cost of water available for boiler feed.

How much feed water heating is required to be done.

The steam turbine itself has, however, one bearing on the situ-
ation, due to the fact that its economy is so enhanced by the higher
vacuum that considerable money may be expended in order to get
this higher vacuum and still remain a profitable investment, so that
after having given due weight to the considerations given above,
the condenser, regardless of the type selected, should be the best
vacuum making machine that can be obtained within the limita-
tions of cooling water and its temperature, in the particular loca-
tion. This is much more true in the case of a turbine than a recipro-
cating engine because a turbine can expand steam much more profit-
ably and to much lower pressure than can a reciprocating engine.
It may be said broadly that an inch of vacuum will affect the steam
consumption of the turbine from three to six percent at full-load,
according to the type and design of the turbine. At fractional loads
the effect of the vacuum is even more marked.

It is proposed in the following pages to discuss the different
types of condensers and point out the particular applications of
each.

PRINCIPLES

The function of a condenser is primarily to condense exhaust
steam by means of cooling water, extracting the non-condensable
vapors by means of a pump, thus permitting the use of a steam en-

gine or turbine designed to expand the steam more nearly to a vacuum and reducing the steam consumption of the engine, by reason of the greater degree of expansion. This is obvious from the following facts:

A pound of dry steam expanded from 140 pounds gauge steam pressure to atmospheric pressure is capable of giving up 131 650 foot-pounds of energy. If it is expanded further to a 28-inch vacuum it is capable of giving up 247 000 foot-pounds in its expansion from 140 pounds. Hence it is seen that about twice as much energy is available in steam by the use of a condenser. Incidentally, there is sometimes another reason for using a condenser, in this case a surface condenser, viz., in locations where no suitable boiler feed water is available and the condensed steam must be returned to the boiler, as on shipboard, for instance. While, as has been shown, the condenser increases enormously the performance and power of the main engine, the power required to operate the condenser is inappreciable inasmuch as the work done by the condenser equipment consists in handling the cooling water; the condensed steam now reduced to, say, 1/330 of its volume as steam, and extracting the non-condensible vapors, all of which, in well designed and well ventilated plants, are inconsiderable items. The power required amounts to from one and one-half to ten percent of the total power of the plant; the power being dependent principally upon the amount of cooling water which has to be handled, against what head it must be pumped, the location of the cooling water, the type of condenser and the type of the prime mover employed to operate the condenser.

CONDENSER DRIVE

Throughout Europe it is customary to employ electric motors, while in America non-condensing steam engines are used almost exclusively. It may be argued in the case of motor driven condensers that the power is received from engines doing the highest possible permormance and hence, allowing for the motor losses, should give a horse-power for the direct driving of the condenser apparatus for as little as 15 pounds of steam per horse-power against, say, 30 pounds in the case of a small non-condensing steam engine. But so long, however, as the exhaust from the non-condensing engine can be properly used in heating feed water, this reasoning in favor of the motor driven outfits fails, as the thermal efficiency of this non-condensing engine, regardless of what its steam consumption

may be, becomes something like 87 percent. Hence as long as this steam is used for feed water heating it does not matter how much power is required to operate the condenser.

ECONOMIZERS

Economizers are more generally used in Europe than in America. An economizer is an arrangement of tubes placed in the path of the flue gases after leaving the boiler, through which the feed water is circulated on its way to the boiler. In well arranged plants feed water may thus be put into the boiler at temperatures as high as 250 and 300 degreees F. In all modern American plants, economizers are similarly used, but with this difference—in Europe very little feed water heating is done before the water enters the economizer, because the amount of exhaust steam available for feed heating is very small, as the condensers are motor-driven. In America, however, it is usual to heat the feed water as much as possible, say, from 180 to 200 degrees, before the water goes to the economizer. It would naturally seem that the thing to do would be to have enough surface in the economizer so as to be able to put cold water in it, heating the water, on the one hand, to the desired maximum temperature and, on the other hand, cooling the flue gases to a minimum, when obviously the boiler efficiency would be that much higher simply due to the fact that all the heat in the gases had been extracted down to, say, normal surrounding temperatures. But if this is done certain troubles will be encountered. The stack temperature will be so low that there will be insufficient draft and some mechanical appliance must be resorted to. For natural draft a stack temperature of 600 degrees F. is considered good practice so that, if natural draft is employed, the gases cannot be cooled down much below this amount.

Considering the effect of cold feed water in the economizer, there are the following objections:—

1—The gases impinging on cold surfaces cause the sulphurous acid gas formed by the combustion of the fuel to be condensed on the tubes, rapidly corroding them. Furthermore, soot is deposited in large quantities, thus reducing the value of the heating surfaces. This latter difficulty is overcome by providing scrapers which are mechanically operated and which, while the boiler is operating, are being continually dragged up and down the heating surfaces, scrap-

ing off the soot as soon as it is formed.   This apparatus consists of
a great deal of gearing, linkage, etc., and is located above and at
the rear of the boilers where it is subjected to dirt and rust, gets
little attention and is an endless source of trouble as soon as it be-
gins to wear out.   Furthermore, there will be the condensation of
tar on the economizer tubes which, with the soot and the sweating,
due to cold surface in the presence of the gases, forms a viscous
mud, causing these scrapers to stick.

2—At certain temperatures carbonic acid in the feed water
corrodes tubes very rapidly. It is most virulent, it is supposed, some-
where between 120 and 150 degrees, but at 180 degrees very little
trouble is experienced from this source.   Hence, it is desirable to
heat the feed water to as high a temperature as possible before it
reaches the economizer.

3—There are also in different feed waters, scale forming salts
which precipitate at temperatures below that of evaporation, so that
if an open heater is employed much of this scale will be deposited
in the heater, where it may be readily removed, instead of in the
boiler and economizer.

4—Since the amount of air that is held in suspension in water
decreases as the temperature rises, the more the feed water is
heated in an open heater the less air will be forced into the boiler.
This latter is harmful because it finds its way to the condenser
and interferes with its performance.   It is also harmful, as
it will promote corrosion in the steam engine and other piping, as it
may sometimes combine with other elements, forming acid.   With-
out oxygen there can be no corrosion.

STEAM VERSUS MOTOR DRIVE

All of the above may seem at first sight very foreign to the
subject of the choice of a condenser, but careful consideration shows
that it is dependent upon such matters, remote though they may
seem.   The discussion shows the advantages of a steam-driven con-
denser and also, in some cases, how inconsequential is the power re-
quired to operate it.   Steam-driven units are furthermore generally
considered by most expert operators of power plants as being more
reliable and certain than electric motors, particularly as they are
generally located in basements where they receive little attention
and are subject to moisture.   In big turbine power plants it may
be stated that more condenser shut-downs have occurred due to the
failure of electrically-driven hot well pumps than all other causes

put together, and in these stations these pumps are the only electrically driven condenser apparatus employed.

It was formerly quite customary to operate condensers with current furnished from the main bus-bars, and sometimes with results disastrous to continuity of operation, due to the fact that with extra heavy loads or trouble outside the power house, the main units would slow down, there would be a fall of boiler pressure and a corresponding decrease of speed in the motors driving the condensers, and hence a consequent fall of vacuum just at the time when the vacuum was most needed. The effect is usually cumulative, often resulting in the whole power plant going over to non-condensing. In the case of one big power plant using motor driven jet condensers it is said that a cycle of events would sometimes occur as above outlined, resulting in one unit after another going to non-condensing, the boiler pressure would fall rapidly, due to the increased steam consumption, which made it necessary to shut down the plant and start up all over again.

If electrically driven condensers are to be used at all, they should be operated preferably from the exciter bus-bars, in which case the condensers would be immune from the above objections so long as the main exciter units had adequate capacity. This is doubly secure, as in all first-class plants of any considerable size the exciter plant is always duplicated and frequently supplemented by storage batteries It may be noted that, if the exciter system fails, vacuum will be of no particular value to the system.

CONDENSERS

The condensers themselves will now be considered, the different types pointed out, their peculiar applications, and the work to be done by the cooling water in the different instances. The arithmetical calculations which determine the amount of cooling water required in a condenser and which exhibit its performance, are the same no matter what type. The ideal condenser is one which will discharge its cooling water at the same temperature as that of evaporation at the pressure of the exhaust system. Naturally such a performance is but seldom realized in practice, although there are instances of its being nearly so. Under proper conditions Leblanc condensers have been known to reach within less than two degrees of this ideal. Ordinarily, however, only first-class jet condensers are able to work closer than ten degrees, fifteen degrees being the allowance which most builders provide in

designing jet condensers. Surface condensers cannot come as close as this because the cooling water and condensed steam are not intimately mixed. Generally speaking, there must be some temperature difference between the cooling water and exhaust. However, the writer has seen tests of surface condensers in Europe in which the air pumps were equipped with Parsons' vacuum augmentors, when as low as four degrees difference have been obtained. This figure of temperature difference, it is to be noted, is the real measure of the performance of the condenser. Some assumption for this figure must be made in determining the amount of cooling water. This determination is as follows:

$$Q = \frac{r}{(t_2 - t_3) - t_1}$$

Where Q = Pounds cooling water required per pound of steam condensed.
t_1 = Temperature of the available cooling water.
t_2 = The temperature of evaporation at the vacuum desired.
t_3 = The temperature difference between outgoing cooling water and t_2 - as outlined above.
r = The heat of evaporation in a pound of the exhaust steam.

Say, for example, that the cooling water t_1, is at 65 degrees. that a 28-inch vacuum is desired, and that the temperature of evaporation at 28 inches vacuum is 102 degrees. Then assume that t_3, the temperature difference expressing the performance of the condenser, is ten degrees, the temperature of the cooling water may be raised from 65 degrees to 102 — 10; i. e., from 65 degrees to 92 degrees. Let us suppose that steam is being condensed from a high grade engine. It is then safe to assume that in expanding enough of the latent heat of the steam has been converted into work so that when it reaches the exhaust pressure, ten percent has been condensed. This is sufficiently exact wherever a high grade engine is employed. The heat of vaporization at 28 inches vacuum is 1043.1 B. t. u. Allowing for ten percent condensation, the heat to be extracted from the steam in order to bring it to water of the same temperature will be 934 B. t. u. Then the ratio of the amount of cooling water required will be $\frac{934}{92-65} = 34.6$; i. e., for every pound of steam condensed, 34.6 pounds of cooling water will be required. The higher the vacuum required and the higher the temperature of injection, the greater will be the quantity of cooling water required. This varying quantity is shown graphically in Fig. 1. These curves are drawn up for a perfect condenser; that is, with no temperature difference, t_3. For any value of t_3 it is sufficient to shift the horizontal scale to the right, thus where a

perfect condenser will produce 29 inches vacuum with 60 degrees water and fifty to one ratio, the actual condenser, say, when $t_s = 10$ degrees requires 105 volumes for the same vacuum. These curves show how rapidly the quantities of cooling water required increase with high vacuum and water temperatures.

EFFECT OF AIR

One of the greatest obstacles to successful condenser performance is the leakage of air into the vacuum space. This need not
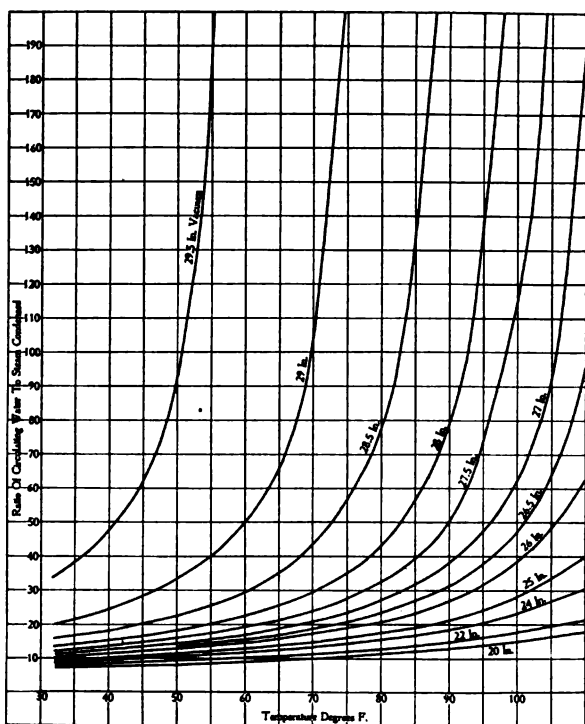
FIG. I—CONDENSER WATER RATIO CHART

necessarily occur in the condenser itself or its attendant piping and valves, but in portions of the steam engine, glands, etc., that are subjected to vacuum. A not uncommon source of air leakage is in the main feed pumps, either through their glands or by drawing air along with the water through the suction.

When the volume to which a quantity of air will expand in a high vacuum is considered, it is readily seen why the work of a

good-sized air air pump will quickly be made useless by
a moderate air leak. Air mixed with steam also af-
fects the temperature of the mxiture generally retarding
condensation. Steam, i. e., vapor and water without air,
has a definite temperature according to the pressure, which
may be found in any steam table. There is, however, a
lower but just as definite temperature for every proportion of air
present. The temperature always corresponds to the pressure of
the water vapor only that is in the mixture, but the pressure of the
mixture is the sum of both the vapor pressure and the air pressure.
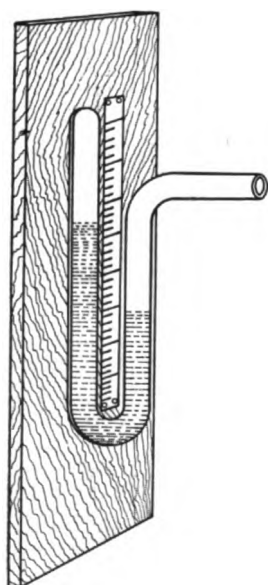
Thus if with a mixture of water vapor
and air in equal parts at a pressure of
one pound absolute, the pressure of the
water vapor itself is at 0.5 pounds per
square inch and that of the air at 0.5
pounds per square inch, the tempera-
ture of saturated water vapor at 0.5
pounds absolute pressure is a little less
than 80 degrees, which will be found to
be the temperature of the mixture. The
pressure of a mixture of air and water
vapor is the sum of the pressures of the
constituent air and water vapor. The
temperature of the mixture will corre-
spond to the temperature of evaporation
of the water vapor at its constituent
pressure. Table I will be useful in il-
lustrating this principle.

In the passage of steam through a
surface condenser to the air pump the
temperature within it will become less and less as the relative pro-
portion of air to water vapor becomes higher as the steam is con-
densed.

MEASUREMENT OF VACUUM

It is conventional to measure vacuum in inches of mercury
below atmospheric pressure corresponding to a 30-inch barometer.
It would be more sensible to refer to vacuum in pounds absolute
pressure or inches of mercury absolute pressure. Generally the
measurement must be made with the atmospheric pressure as a
basis and converted to absolute pressure afterwards by making

proper correction for the barometer. There is one instrument, however, called an "Absolute Vacuum Gauge" for which no barometric correction is necessary. It consists of a U-tube like Fig. 2 with one end sealed and filled with mercury with the air expelled in a manner similar to a mercurial barometer. The absolute pressure

TABLE I

Temperature Degrees F.	Pounds per Sq. In. Abs., No Air Present.	Inches Vacuum Referred to 30" Barometer, No Air Present.	Pounds per Square Inch Absolute						
			.49	.98	1.47	1.96	2.45	2.94	14.697
			Inches Vacuum Referred to a 30-Inch Barometer						
			29	28	27	26	25	24	0
			Percent Volume of Saturated Air Present in a Mixture of Air and Vapor of Water						
60	0.2545	29.48	48.0	74.0	82.6	87.0	89.5	91.4	98.4
70	0.3602	29.26	26.5	63.0	75.5	81.5	85.5	87.8	97.6
80	0.5027	28.97	....	48.6	65.8	74.3	79.5	82.9	96.7
90	0.6925	28.59	....	29.4	52.9	64.6	71.8	76.4	95.4
95	0.9421	28.35	....	17.4	45.0	58.7	67.0	72.5	94.6
100	0.0421	28.08	....	3.87	35.9	51.9	61.5	67.9	93.7
105	1.0938	27.77	....	....	25.6	44.2	55.3	62.8	92.6
110	1.2663	27.42	....	....	13.8	35.4	48.3	56.9	91.4
112	1.3416	27.26	....	....	8.7	31.6	45.3	54.4	90.9
114	1.4207	27.10	....	....	3.3	27.5	42.0	51.6	90.4
116	1.5039	26.93	....	....	...·	23.3	38.6	48.9	89.8
118	1.5912	26.75	....	....	...	18.8	35.05	45.85	89.3
120	1.6828	26.57	....	....	...	14.1	31.3	42.8	88.6
122	1.7789	26.37	....	....	...	9.3	27.4	39.5	88.0
124	1.8797	26.17	....	....	...	4.1	23.3	36.1	87.3
126	1.9852	25.95	....	....	...	...	18.96	32.5	86.6
128	2.0959	25.73	....	....	...	...	14.45	28.7	85.8
130	2.2119	25.48	....	....	...	...	9.72	24.8	85.0
132	2.3333	25.24	....	....	...	...	4.77	20.6	84.2
134	2.4603	24.90	....	....	...·	...	...	16.3	83.3
136	2.5932	24.71	....	....	...	...	...	11.8	82.5
138	2.7321	24.42	....	....	...	...	...	7.07	81.5
140	2.8774	24.13	....	....	...	...	...	2.13	80.5

in inches of mercury is the difference in levels between the mercury in the two sides of the U-tube. If the mercury level were the same in each it would be reading a perfect vacuum. This instrument is not very reliable as a portable instrument, as the least air leakage causes material error, and for this reason it is not much used.

In reading vacuum by means of a mercury column, correction must always be made for the barometer, and sometimes when great accuracy is desired, as in a test, correction must also be made for temperature. The correction for the barometer is the difference between the actual barometer reading and 30 inches, the difference being added to the mercury column reading when the barometer is less than 30 inches and subtracted when the barometer is greater than 30 inches. Thus a high altitude with a 24-inch barometer, for instance, a 22-inch vacuum reading by mercury column would correspond to a 28-inch vacuum at sea level. At this altitude an engine exhausting to atmosphere would actually be operating with a six-inch vacuum referred to sea level and would have this much advantage over an engine operating at sea level.

Regarding temperature, a barometric column of 30 inches in height at 62 degrees F. corresponds to the standard atmosphere of 14.7 pounds per square inch; the 30 inches height varying with the specific gravity of mercury at different temperatures. When a mercurial barometer is used and it is located in close proximity to the mercury column, no temperature correction is necessary, as it would only apply to the difference between the barometer and the column and would hence be very inconsiderable. When an aneroid barometer is used, the temperature must be taken into account, as these barometers are usually adjusted to read the atmospheric pressure referred to 32 degrees F., which is the basis used by the Weather Bureau.

Sometimes during a test the only means of getting a barometer reading is to call up the local Weather Bureau. In doing so the government observer will always give the reading referred to sea level and 32 degrees F., which is not of much use without knowledge of the altitude. A point to look out for in tests is to be sure the mercury is pure. Unscrupulous men representing condenser builders have been known to adulterate mercury with tin or something that will readily amalgamate with mercury, thus reducing its specific gravity and making the condenser appear to be pulling a better vacuum than it actually does.

(To be continued.)

A BROADER TRAINING FOR ENGINEERS*

CHARLES WHITING BAKER
Editor, Engineering News

NO man builds a mill to produce even such staples as flour or cotton cloth, without carefully examining market conditions. It is fitting, therefore, that we survey the market conditions for engineers. How stand the relations of demand and supply? What sort of engineers are most needed to-day? What grade of flour will you set your mill to grind?

Perhaps I can best picture to you market conditions in the engineering profession if I draw a parallel between the engineer and one of his favorite materials—Portland cement.

A quarter of a century ago, Portland cement was an expensive and little-used article—just like the engineer of a somewhat earlier period. The valuable qualities and many uses of Portland cement were little appreciated when it was first introduced. The pioneer engineers suffered in like manner. To-day fifty huge mills are producing Portland cement where there was one a generation ago. So where there were four small struggling schools of engineering in the United States in 1850, there are to-day more than fifty times that number. Undoubtedly the increase in cement mills and in engineering schools has had the effect in each case of lowering the price of the product. But it is also true that this low price combined with excellent quality has enormously increased the demand, both the demand for cement and the demand for engineers.

Is the engineering profession overcrowded? Are its members underpaid? If you submit these questions to a jury of engineers, you will, I am sure, receive an affirmative verdict. But I suspect you would have the same sort of answer if you inquired of lawyers concerning the legal profession or of physicians as to the practice of medicine.

I freely subscribe to the statement that the engineering profession as a whole is not paid in proportion to the responsibility it carries and the useful service that it renders to the community; and yet I cannot believe it for the benefit of engineers or of the

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*Condensed from an address delivered at the dedication of Smith Hall of Engineering, Northwestern University, Evanston, Ill., May 7th, 1909. An excellent address of local interest was also delivered by the director-elect of the new engineering college, Mr. John F. Hayford, of the U. S. Coast and Geodetic Survey. Mr. Hayford is the author of the article "Study Men" in the JOURNAL for October, 1907.

public to have the path into the engineering profession made too easy or the rewards for the lower grades of engineering work too great.

When the question is squarely put whether there are too many engineers, I am obliged to answer, there are none too many good engineers even though there be a surplus of poor ones. If engineers are underpaid, as I believe they are, it is because the public which employs engineers does not yet appreciate how valuable high-class engineering work is. Somebody has defined an engineer as a man who can do with one dollar what any fool can do with two. When all members of the profession appreciate and act on that definition, the public can well afford to pay princely salaries to its engineers.

I depreciate that competition in the engineering profession which lowers the pay of engineers. Competition in engineering ought not to be in the rate of pay but in the quality of service A few days ago I received a letter from an official Board asking what would be a proper salary to pay an engineer for taking charge of a piece of hydraulic construction involving an expenditure of a million dollars. I replied that the salary they should pay ought to depend on the sort of man they secured. If they engaged a man of exceptional ability he would probably save them so much in the cost of the work that they could well afford to pay him twice or thrice what they would pay an ordinary engineer.

But every member of the profession who has reached mature years, held large responsibilites and come in contact with engineers of all sorts in actual work, will confess that a very large amount of work is done poorly that ought to be done well, that many, many millions of dollars are wasted that might be saved by better design, better supervision, better execution. Engineers, let us confess, are not exempt from the frailties of humanity. Some of us are lazy, and will take the easy course and let things run on in the rut of routine rather than make the effort to prepare new designs to meet changed conditions. Some of us are arrant cowards, and rather than run any risk we will spend money like water—so long as it is not our own money. I have seen engineers of this type take credit to themselves for their conservatism, and prate in official reports about the high-class construction they had secured, when the fact was that they had spent thousands where hundreds would have satisfied every requirement.

I am perfectly well aware that there are men who defend that type of engineering. They claim that an engineer's business is only to look after accuracy, strength, permanence and safety in construction, to use only the best materials and accept nothing but the highest class of work. It is the engineers of this type who are responsible for the idea, still too commonly held, that to put an engineer in charge of work means a great increase in its cost. If we had less such engineering there would be a greater demand for engineers.

Engineering education, like any other education worthy of the name, is a process of growth. Unless a boy has natural abilities of the right sort you cannot make him into a good engineer. On the other hand, boys with good natural abilities who cannot afford a college training are going out into the working world all the time, beginning at the bottom rung of the ladder in some line of engineering industry, educating themselves in the school of daily experience, aiding that development by study in their night schools and correspondence schools and by wide reading and observation. I want to leave a wide door open into the engineering profession for the men who obtain their education in such a way.

For the past twenty years, the engineering colleges of the United States have been specializing their instruction in engineering by multiplying the number of their courses, by trying to make men expert in one particular branch of engineering work. I am far from denying that there is a large demand and a certain field of usefullness for such special courses; but I believe that there has been too much specialization in our engineering instruction. We have to-day in the engineering profession many specialists, but too few men with broad knowledge, broad abilities and a broad outlook. The business of the engineering college is to lay a broad, secure foundation. I am not objecting, mark you, to schools of a different sort. There is room and need for correspondence schools, for night schools, for industrial schools, for schools that give special instruction in special fields. But to give young men an education that will best fit them for high and responsible positions in the engineering world, you must make your training a broad foundation.

The country to-day needs engineers of high type as it never has needed them before. Few realize the enormous change that has taken place in the relations between the engineer and the public. Go back less than a century and you find the engineer almost un-

known.   Civilization and industry knew his prototype—the mill-wright, the builder, the miner; but their art was the art handed down by tradition.   The application of science and the scientific method to industry had barely begun.   Civilization now finds it-self face to face with a multitude of perplexing problems.   A large number of these problems are so interwoven with our industrial de-velopment that the engineer is needed to aid in their solution.

I want to see more engineers who are able to wisely solve this problem, "What is worth while," in a hundred lines of engineering work.

Is it worth while to spend two hundred million dollars to build one kind of a lock canal at Panama, or three hun-dred millions to build the one we are now completing, or five or six hundred millions to build a sea-level canal?   Is it worth while for the government to spend half a billion dollars on waterway improvements?   Is it worth while for a state to spend a million or ten millions on good roads?

How many hundreds of millions of dollars do you suppose are expended annually in the United States in the promotion of foolish and absurd inventions or enterprises wrongly planned?   It has long been a theory of mine that people ought to be saved from losing their money in such schemes by seeking the advice of engineers.   But I have found that before my theory can be put into practice we must have engineers who are wise enough and broad enough to give re-liable advice on such matters.   And the public must learn to dis-criminate between the engineers who know and those who only think they know.

I know engineers who shirk these questions; who say that the engineer should take a humble back seat while the statesman, the lawyer, and—if you please—the ward alderman decide these ques-tions.   This is a huge mistake.   The opportunity for leadership is open to the engineer.   His technical knowledge is essential to the wise solution of public problems.   Can he couple with his technical knowledge those other qualities which are essential.   And what are some of these qualities.   First of all, what I may term the judicial spirit.   An engineer has no business to be governed by prejudice or partisanship.   His sole object ought to be to find where the truth lies.   He constantly makes choices in his daily work, and sound judgment in such choices is a first requisite.   Of course, he must have the knowledge on which to base a judgment;

and yet when I am asked to recommend an engineer for large responsibilities, I look first of all for a man of broad mind, one who is able to weigh matters fairly and judge without prejudice.

If technical students can have developed those qualities of mind and heart and character which will in later years ripen into sound judgment, they will gain something much more rare and valuable than knowledge of hydraulics or expertness in the testing laboratory.

I grant you that a proper mental equipment in the student is essential at the start; but given that, ought not the college years—the formative period of a man's life—be made effective in cultivating just such qualities? Do not our American colleges and universities miss their highest opportunity if they fail to develop in their students a broad outlook, fair-mindedness, keenness to discern error, love of the truth?

And there are other qualities. Tact—the combination of good judgment with good taste in dealing with others; self-confidence without self-conceit; a personality that attracts men, wins their confidence, holds their loyalty.

I want to protest against the too-common standard by which we rate the success of men. You tell me that this graduate holds a $25 000 position, that another owns a rich copper mine and a third is president of a colossal trust. Have they achieved success? Very likely; but why not apply to them the same standard that we apply to your university?

The true measure of success, alike for the university and for its graduates, is the test of public service.

I know an engineer who has through long years guided the destinies of a great city, saved to its taxpayers untold millions of dollars, fostered its development in a way that will benefit generations yet unborn.

I know an engineer who has turned a barren desert into fruitful farms and has made possible prosperity and happiness to thousands and tens of thousands.

It is true that the public seldom appreciates the value of such services as these, and those who render such service often receive only meager reward; and yet I tell you that it is achievements like these that best deserve the name of success.

DISTRIBUTING TRANSFORMERS

AS OF INTEREST TO CENTRAL STATIONS*

E. G. REED

THE purpose of this paper is to briefly trace the development of the distributing transformer; to show the essential requirements of transformers of this class; to discuss their electrical and mechanical characteristics, and to indicate their probable future development.

In the early days of the transformer it was used only for the distribution of electric current for lighting, directly to the consumer, but as the alternating-current system developed other transformers were required. The term "distributing transformer," here used, is intended to apply to those units delivering energy directly to the user.

FIG. I—GAULARD AND GIBBS TRANSFORMER

Original British patents dated 1882.

HISTORICAL

From the classical experiments of Joseph Henry, published in 1832, was developed the induction coil, which is the prototype of the modern transformer. The

FIG. 2—STANLEY TRANSFORMER AS BUILT IN 1885

first practical transformer was patented in England in 1882 by Gaulard and Gibbs The American patent rights were purchased in 1886 by the Westinghouse Company. The construction of the Gaulard and Gibbs transformer is shown in Fig. 1. From 1883 to 1885 William Stanley, Jr., while in the employ of George Westinghouse, experimented with the converter, the name by which the transformer was then commonly known. In 1885 Stanley built transformers of the type shown in Fig. 2, and this became the commercial form used by the Westinghouse Company for many years. During the year 1886 that company built transformers for commercial use,

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of the type shown in Fig. 3, the winding and magnetic circuit being substantially that shown in Fig. 2.

The terms "core" and "shell" type were introduced about this time to denote the difference between transformers like that of Gaulard and Gibbs, in which the iron forms a core or center portion on which the windings are placed, and those in which the iron encloses the coils like a shell, as in the Stanley form shown in Fig. 2.
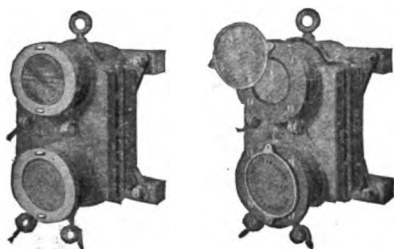
FIG. 3—EARLY WESTINGHOUSE TRANS-
FORMERS, MANUFACTURED IN 1886

In the years 1887 and 1888 an endeavor was made to secure legislation against the use of alternating current for the distribution of power, the experience of Mr. Westinghouse in the introduction of the alternating-current system of distribution, being, therefore, somewhat similar to his experience in introducing the air brake into general use. The Thomson-Houston Company brought out a shell-type transformer in the year 1888. This type of transformer, shown in Fig. 4, continued to be used down to as late as 1895.

After the first commercial transformers were made, the immediate developments were improvements in detail on the shell type of construction. The use of oil as an insulating and cooling medium was generally adopted, and both the iron and copper losses were reduced and the regulation improved. The transformers were modified to meet the requirements of 60-cycle service, the first design being built for 133-cycle operation, this frequency being then in general use. About 1899 to 1901, designs were developed indicating a close approach to the ideal transformer, as in the Berry patents taken out in England about this time. (See Fig. 5.) The same ideas, however, were foreshadowed in the original patent (See Fig. 6), granted George Westinghouse, May 25, 1886. The original conception has been developed toward the ideal construction, which, however, can not be completely realized on account of limitations
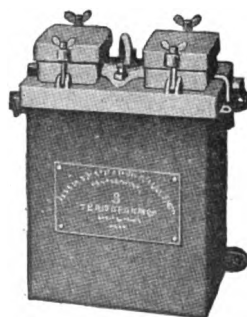
FIG. 4—EARLY THOM-
SON-HOUSTON TRANS-
FORMER
Made in 1888.

in the materials, iron and copper, of which actual transformers are constructed.

The ideal transformer may be described as the design in which the mean turn of both iron and copper will enclose a maximum area for a given amount of material. This will result in a design of the least amount of material and lowest cost to obtain a given performance. The ideal transformer, as shown in Fig. 7, is one in which either the iron or the winding is formed into an annular ring and the other elements into a circular form about this ring completely filling its opening. Further limitations beyond that of the materials used in building transformers, such as hand labor and the requirements of ventilation, space for terminals, and other details of construction, prohibit the actual building of the ideal transformer.
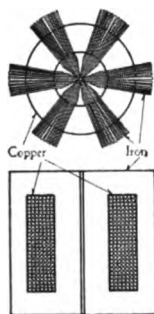
FIG. 5—BERRY TRANSFORMER

Fig. 8 shows the construction of the latest form of the shell type for distributing transformers and is a practical construction approximating the ideal shape.
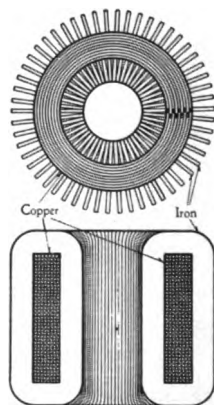
FIG. 6—EARLY WESTING-HOUSE TRANSFORMER
Patent date, 1886

The limitations imposed by the character of the magnetic materials used is aptly offset by increasing the section of the magnetic circuit outside of the winding. This permits an increase in the magnetic circuit without a corresponding change in the conductors which would have been necessary with the
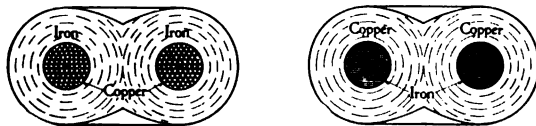
SHELL TYPE   CORE TYPE
FIG. 7—IDEAL TRANSFORMERS

other forms of design. The core type of design, which is a counterpart of the shell form in Fig. 8, is shown in Fig. 9. The refinements found in the best modern designs of core and shell type reduce considerably the difference which formerly existed between

them. In high-voltage work the core type of construction, depending on the size of the transformer, finds its best field, and hence both forms of construction are justified. The efficient disposition of the insulation possible with the core-type transformer in higher voltages is the reason for its use.

The simplicity of the magnetic circuit in the best design of this
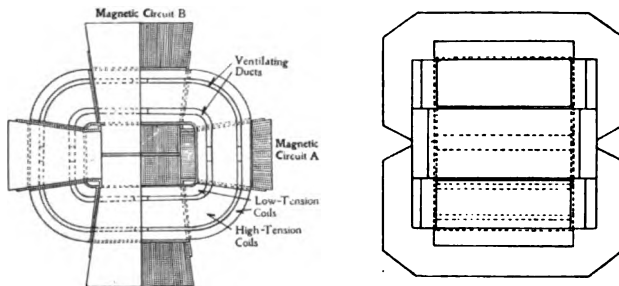
FIG. 8—LATEST FORM OF THE SHELL-TYPE TRANSFORMER

improved form of the shell type is illustrated in Fig. 10 and its merits are shown by the test results given in Fig. 11. The shell type of transformer requires one group of coils, instead of two or four as in the core type. The addition of the two iron circuits to the former shell construction protects the remaining two sides of the coil and the winding is practically armored.

FIG. 9—CORE TYPE TRANSFORMER

Counterpart of latest shell-type.

The comparatively recent advent of silicon or alloy steel has affected both the design and performance of distributing transformers. Its use does not change the relative economy of the different types of construction, but its increased cost does change the proportions of copper and iron in any particular design. The lower loss per unit of weight of the iron would naturally allow a saving of material for a given performance. This would result in an increase of the flux density in the iron and of the current density in the copper, their upper limits being set by the magnetic saturation of the iron and heating of the copper. The general effect of the better material on commercial transformers, however, has been to increase their efficiency, better their regulation and to reduce their size and weight without increased cost to the buyer.

In the early days of transformer designing the proportions were worked out roughly by rule of thumb, the main requirement beng to build transformers that would operate. For a considerable period it was thought that there were so many quantities involved in the design that it would not be practical to take them all into consideration and make a theoretical design. In the manufacture of modern transformers this method of treatment has been demonstrated to be the only successful one to use.
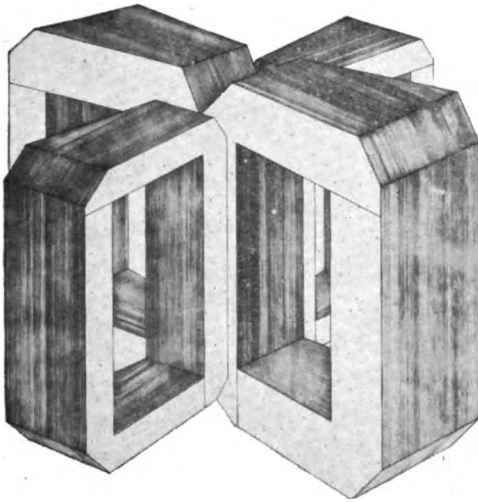
FIG. IO—MAGNETIC CIRCUIT OF THE LATEST FORM OF THE SHELL-TYPE TRANSFORMER

The relative costs of iron and copper are taken into account, and the most efficient design is made for the existing market value of these materials. Mathematical methods of design produce transformers that are uniform in their characteristics, the sizes progressing in dimensions, weight and performance in a uniform manner. This is indicated in Fig. 11, showing the losses for a line of commercial transformers.
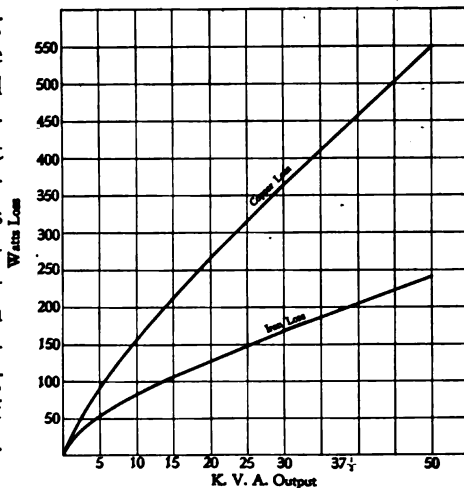
FIG. II—IRON AND COPPER LOSS CURVES
Transformer of recent design.

SERVICE REQUIREMENTS

The service requirements of transformers mounted on poles or in manholes are identical as to performance, but differ in most other par-

ticulars. Regarding performance, it goes without saying that the iron and copper losses should be low; in fact, the development of distributing transformers during the past twenty years has been largely one of reducing these losses. Low iron loss is particularly important, since it is continuous and therefore should be smaller than the copper loss, which occurs only when the transformer is l o a d e d. Since the regulation is practically proportional to the copper loss, the extent to which the iron loss of a transformer of given cost may be reduced by increasing the copper loss is limited by he necessity of securing good regulation. For example, the regulation of a one k. v. a. transformer, as shown by the curves in Fig. 12, is 2.62 percent, which value can not be greatly increased without rendering the transformer unsuitable for ordinary service. On the other hand, the regulation of a 50 k. v. a. transformer is

FIG. 12—REGULATION CURVES.
Transformer of recent design.

1.15 percent, and this value might be increased without jeopardizing satisfactory service. The iron loss might be reduced by increasing the copper loss if this change would result in a net saving. For a transformer of given cost, as the iron loss is reduced and the copper loss increased, a point is reached beyond which a further decrease in the iron loss can be made only by a very considerable increase in the copper loss. This

FIG. 13—CURVE SHOWING RELATIVE VALUES OF IRON AND COPPER LOSSES

is shown by the curve in Fig. 13, which represents the relation between the losses which can be obtained with various designs having the same cost. The curve shows that if the iron loss be decreased to 90 percent of its normal value, the copper loss increases

to 113 percent of its original value. However, decreasing the iron loss to 60 percent of its normal value, would increase the copper loss to 183 percent of its original value. This should be taken into account in proportioning the losses, which for a given transformer should be so related that the cost of supplying them for a given period shall be a minimum.

It is usual to consider the total cost of supplying transformer losses to be made up of the actual cost of producing current, say one cent per kilowatt-hour, and a fixed charge for interest, depreciation, and the like, on the station equipment, of, say, $20 per kilowatt-year. The total cost of supplying one kilowatt-year of iron loss at one cent per kw-hr. for 365 days of 24 hours, amounts to $87.60 plus the fixed charge of $20, or a total of $107.60. Assuming the daily load on the transformer to be equal to four hours of full load, the actual cost of the power used per kilowatt of copper loss will be one-sixth of the cost of power used per kilowatt of iron loss, or one-sixth of $87.60 equals $14.60. Thus the total cost per kilowatt-year of rated transformer copper loss will be $14.60 plus the fixed charge of $20, or $34.60. The cost of supplying the losses of a modern five k. v. a. transformer having an iron loss of 45 watts and a copper loss of 93 watts, will be :—

Cost per year of iron loss equals   0.045 × $107.60 = $4.84
Cost per year of copper loss equals 0.093 × $34.60 = $3.22

Total Cost $8.06

This transformer has a copper loss that is approximately 2.1 times its iron loss, and it can be shown theoretically that, for the cost of power as given above, the best results would be obtained if the copper loss were 2.4 times the iron loss. The losses of a line of commercial transformers are shown in Fig. 11, in which the average copper loss above the smaller sizes is 2.1 times the average iron loss.

The query next arises, Why are transformers not made having lower losses than those just referred to? The answer to this is that improved apparatus is not readily saleable unless the saving resulting from its use is more than the cost of carrying the additional investment. If the five k. v. a. transformer before referred to costs $60 and the interest and depreciation on this investment is 15 percent, the total annual cost of operating this unit is $9.00 plus $8.06 = $17.06. If it can be shown that the losses of this trans-

former can be reduced at a cost which will make the total cost
of its operation less than $17.06 per year, a more economical trans-
former for these conditions could be designed. The performance
of modern transformers is more the result of a growth and adjust-
ment than of theoretical considerations. The factors entering into
the cost of power are so variable, and the questions of transformer
costs so intricate, that a general solution is hardly possible. It is
usual for transformer manufacturers to carry two lines of trans-
formers, one having relatively lower iron losses than the other, the
difference in price being approximately 15 percent. The curves in
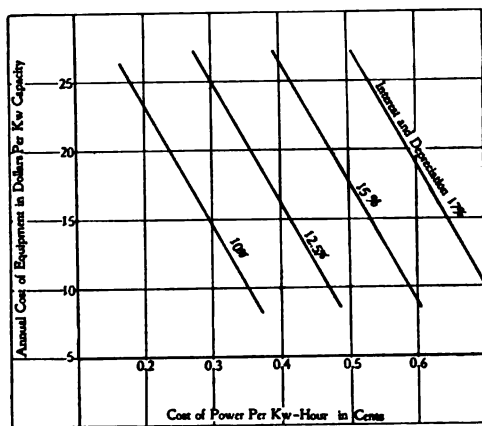
FIG. 14—COST CURVES
Showing relative value to central station of
transformers of different efficiencies for vari-
ous values of power cost, interest and depre-
ciation.

Fig. 14 show for what
cost of power, fixed
charges, and the like, it
is equally economical to
use either grade of
transformer. For, in-
stance, if the annual
cost of the equipment is
$20 and interest and de-
preciation on the trans-
former investment is 15
percent, and if power
costs approximately 0.5
cent or more per hour,
it is more economical to
use the first-grade trans-
former. These curves
are drawn for a partic-
ular size of transformer,
taking into account its actual cost and losses and the difference in
cost and performance between it and the corresponding size of
the other line. The general results, however, will apply to a whole
line of transformers, as they differ in all sizes by approximately
the same amount in cost and performance.

The exciting current of a transformer may be defined as the
current taken by the high-tension winding when the low-tension
winding is not loaded. Heretofore the magnitude of the excit-
ing current of distributing transformers has not been given much
attention, due to the fact that with the older grades of iron a
low exciting current naturally resulted from a normal design.
The use of silicon steel has modified designs in such a way that

without considerable care in design and manufacture high exciting current result. For this reason, to-day the question of exciting current must be considered when buying transformers. It is not generally appreciated that the exciting current of a transformer is the cause of a copper loss in the line and in the generator, which is continuous so long as the transformer is connected to the mains. This is a true energy loss and must be placed in the same class as the iron loss. With a load having 100 percent power-factor, the loss resulting from the exciting current is constant and independent of the value of the load. The lower the power-factor, the greater will be the copper loss due to the exciting current. For example, assume that a distributing line is loaded with transformers which take an exciting current such that the magnetizing component is five percent of the full-load current. How does the operating economy of this transformer compare with one having a magnetizing component of, say, 15 percent, assuming that the power-factor of the load external to the transformer is 100 percent and that the normal line loss is 15 percent of the power delivered? Assuming further that the transformers have a normal
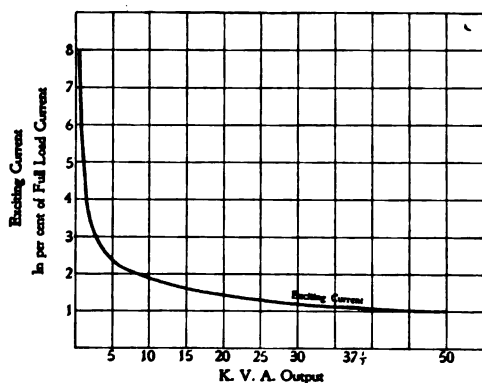
FIG. 15—EXCITING CURRENT CURVE
Transformer of recent design.

iron loss of one percent, the first case will result in a line copper loss which is equivalent to increasing the iron loss of the transformer by approximately four percent. For the second case, a line copper loss results which is equivalent to increasing the iron loss of the transformers by approximately 34 percent. In the case of a 60 percent power-factor ,the first transformer produces line losses equal to increasing the iron loss approximately 125 percent and in the second case approximately 400 percent. In the case of the transformer having 15 percent magnetizing component, the increase in line loss will be equal to an increase in transformer iron loss from a minimum of 30 percent at 100 percent power-factor to a

maximum of 400 percent at 60 percent power-factor, having intermediate values depending on the magnitude of the load and its power-factor. Hence the presence of large magnetizing current will, under certain conditions, produce much greater loss than the total iron loss of the transformer and on the score of efficiency it is important to consider magnetizing current as well as true iron loss. The exciting current of commercial transformers of various sizes is shown in Fig. 15.

Aside from this copper loss, a considerable portion of the generating equipment must be operated at periods of light load on the transformers merely to supply exciting current. The use of transformers having a high exciting current also causes a lower power-factor on the whole distributing system, thus affecting the regulation not only of the transmission line and the transformers, but the generating equipment as well. Thus, with a load that naturally has a good power-factor, the introduction of transformers with high exciting currents tends to materially reduce this p o w e r - f a c t o r. Again, with loads having low power-factors, the use of such transformers will still further reduce the power-factor. High exciting
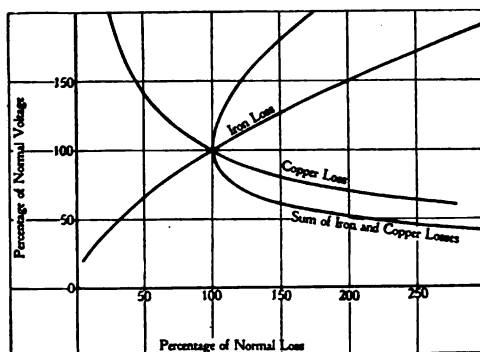
FIG. 16—CURVES SHOWING CHANGE OF LOSSES WITH VARIATIONS IN IMPRESSED VOLTAGE WITH CONSTANT K. V. A. OUTPUT

current indicates that the iron in the transformers is worked near the knee of the saturation curve, or a little past the knee. Thus an increase in the voltage of the system will run the saturation of the iron beyond the knee of the curve and produce an extremely high exciting current.

OPERATING CHARACTERISTICS

The relative values of the iron and copper losses in a transformer may be varied by changing the voltage impressed on its primary winding, the load current also being changed so that its kilovolt-ampere output remains constant. The output of a transformer is regularly rated in kilovolt-amperes, or the products of the secondary voltage and the current delivered to the load. Thus if

the voltage delivered by the transformer is decreased, the current must increase if its output is to remain constant. The induction in the magnetic circuit, varying with the impressed voltage, increases or decreases the iron loss. When the voltage is low the current in the winding is large, consequently the copper loss is increased, and when the voltage is high the current and the copper loss are low. The curves in Fig. 16 show in a graphical way the relation between the copper and iron losses and their sum as the impressed voltage varies; the kilovolt-ampere output remaining constant. It is apparent that when the iron loss reaches low values the copper loss increases very rapidly. On the other hand, when the copper loss in turn reaches its low values, the iron loss does not increase so rapidly as did the copper loss. It is interesting to note that as the
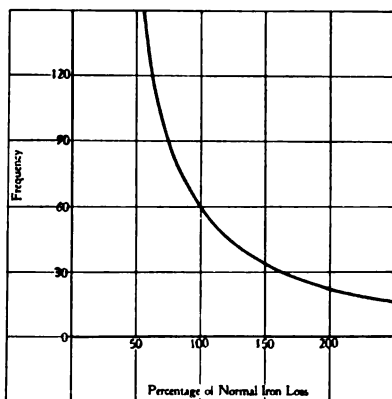
FIG. 17—CURVE SHOWING CHANGE OF IRON-LOSS WITH FREQUENCY

iron loss increases and the copper loss decreases, the sum of the losses decreases until a minimum is reached, after which it again increases. It is apparent that the sum of the losses is a minimum somewhere in the region of equality of the iron and copper losses. In the variation of the losses by changing the impressed voltage, it has been assumed that the voltage change is not limited by the satura-

tion of the iron. In a practical case, the saturation of the iron might prevent any considerable variation of the voltage above normal. The relation of the iron and copper losses in any transformer, if the sum of their losses is to be a minimum, is that the iron loss should be approximately 15 percent greater than the copper loss. This is a perfectly general relation, and for a transformer of any capacity, voltage or frequency and of any type of design, if the losses are in this relation their sum will be a minimum.

In the preceding case the losses were varied by changing the impressed voltage and keeping the output and frequency constant. Fig. 17 shows the variation of the iron loss for a given transformer with changing frequency at the supply circuit. The question is one of variable iron loss only, as evidently the copper loss is not affected

by changing the frequency of the current. Assuming the iron loss and the copper loss to be constant, the output of a transformer is related to the frequency at which it is operated, as shown in Fig. 18. The output of a transformer, for example, at 25 cycles, is approximately 70 percent of its output at 60 cycles. Fig. 18 gives the output of a transformer at various frequencies in terms of its output at 60 cycles.

It can also be shown that the output of a transformer is approximately proportional to the three-fourth power of its weight. This assumes that the loss densities in the materials, iron and copper, making up its structure are maintained constant.

Transformers operating at a temperature of 100 degrees C. will probably soon fail, and assuming an average temperature of the air of 25 degrees C., this limits the maximum permissible temperature rise of the transformer to less than 75 degrees C. Allowing for a margin of, say, 10 to 15 degrees C., gives a safe operating temperature rise of from 60 to 65 degrees C. This refers to the temperature rise of the windings and not that of the surrounding oil, which obviously must be cooler.* In good commercial transformers, depending on the size and on the cooling efficiency of the oil ducts through the windings, the temperature of the windings is

FIG. 18—CURVE SHOWING CHANGE OF OUTPUT WITH FREQUENCY IN PERCENT OF OUTPUT AT 60 CYCLES

from five to 15 degrees above that of the hot oil in the upper part of the case. The temperature guarantee of standard distributing transformers is 50 degrees C. rise of the windings after continuous operation at normal load. If this guarantee were based on oil temperatures, rather than that of the windings, a guarantee of approximately 40 degrees C. could be made, instead of 50 degrees C. In determining the permissible load at which commercial transformers can be operated for a given time, and the permissible time for a given load, this maximum operating temperature must not be exceeded. Having plotted from tests, the curves showing the increase of the temperature rise of the oil and windings with time, starting with 100 percent transformer load, it is possible to determine the corresponding curves for any other load.

*See the JOURNAL Question Box, No. 276.

The calculation of overload temperature curves is based on the fact that the temperature rise of the oil is proportional to the total loss in the transformer and the temperature rise of the windings above the oil is proportional to the copper loss. Suppose it is desired to draw the temperature rise curves for 125 percent load. Assume that after eight hours operation at 100 percent load the oil rise is 34 degrees C. and the rise of the windings is 45 degrees. If the normal iron loss of the transformer be 33 percent and the normal copper loss be 66 percent of the total loss, a load of 125 percent will produce a copper loss of 104 percent, the copper loss increasing as the square of the load. The total loss for this load will then be 137 percent, therefore the temperature rise of the oil will be
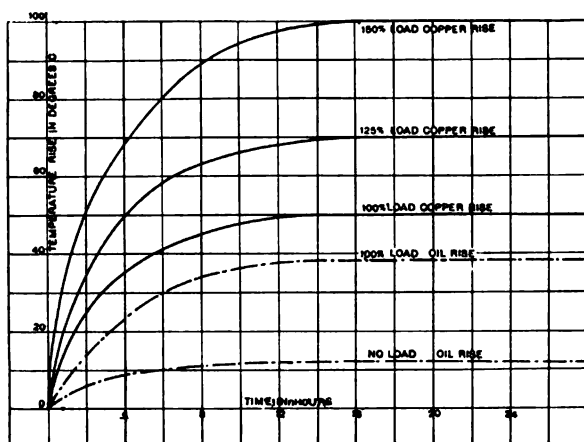
FIG. 19—TEMPERATURE RISE CURVES

$1.37 \times 34°$ C.$=46°$ C. The rise of the copper above the oil will be $1.56 \times 11°=17°$ C. The temperature rise of the copper will then be $46 + 17 = 63$ degrees C. This procedure can be repeated for a sufficient number of points to enable the construction of the complete temperature curve. The temperature rise curve of the windings for no-load, that is, the temperature rise due to the core loss only, can be determined by the same method. If the normal core loss is 33 percent of the total loss , the temperature rise of the oil and the winding also will, in this case, be $0.33 \times 34 = 11$ degrees C.

The curves given in Fig. 19, which show the rise of the oil at no-load and at 100 percent load and the copper at 100, 125 and 150 percent loads, have been determined by test, and they check up very closely with the theoretical curves as outlined above. The

temperature rise of the oil is determined by a thermometer and of the windings by the increase of resistance method. These curves do not represent any particular size of transformer, but rather the characteristics of a modern line of distributing transformers of from one to 50 kilovolt-amperes.

From the temperature curves shown in Fig. 19, time over-load curves can be drawn, an example being shown in Fig. 20. These indicate the time required for any load to increase the temperature of the transformer to any specified temperature rise. If the transformer is cold when the load is applied, it will require a slightly longer time to reach the predetermined rise than if it has already attained the temperature due to the core loss. This difference is not considerable and for practical purposes may be ignored. From the curves given in Fig. 20, it is possible to determine the temperature rise of a transformer under almost any conditions that may arise in service. There are two kinds of problems:—

First—What will be the temperature rise of a transformer under given conditions of load for a certain period of time?
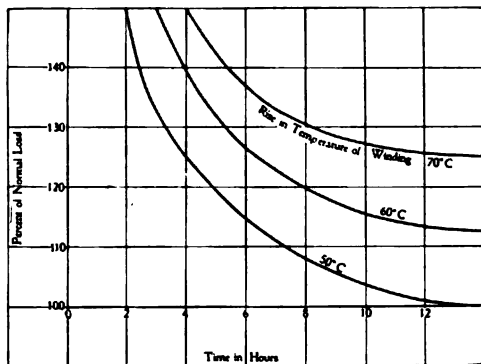
FIG. 20—TIME OVERLOAD TEMPERATURE CURVES

Second—What period of time will a transformer carry a certain load without exceeding a limiting temperature rise?

As an example of the first case, suppose it is required to find the temperature rise of a transformer that is operating with no-load and then receives a 100 percent load for four hours, followed by a 150 percent load for two hours. From the temperature curves in Fig. 19, it is seen that the winding have approximately a 12-degree rise, due to the iron loss only. To obtain the temperature rise of the windings after four hours at 100 percent load, follow the 100 percent load temperature rise curve forward for a period of four hours from the point where it reached a temperature rise of 12 degrees C. This gives a temperature rise of approximately 38 degrees. When the 150 percent load is placed on the transformer it has a temperature rise of 38 degrees C., and will then con-

tinue to rise in temperature as indicated by the 150 percent load curve. Starting from the 38 degree C. rise, on the 150 percent load temperature rise curve, a transformer at the end of a two-hour period will have reached an approximate temperature rise of 63 degrees C. In this case its original temperature rise, due to its core loss, had little effect on its final temperature. Although it had a temperature rise of 12 degrees C. when the 100 percent load was started, this increased its temperature rise only 2 degrees C. at the end of the four-hour run at 100 percent.

As an example of the second phase of the problem, suppose it is required to determine what load is required to produce a temperature rise of 70 degrees C., after six hours' run. It is necessary in this case to refer to a 70 degree time overload curve. From the curve shown in Fig. 20, it is seen that a load of 137 percent is required to bring the transformer to the required rise.
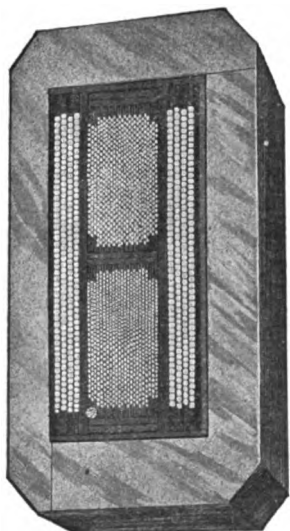
FIG. 21—SECTION THROUGH TRANSFORMER MAGNETIC CIRCUIT AND WINDING

FUTURE DEVELOPMENTS

If the present iron is used at a higher induction it becomes oversaturated, giving high exciting currents. A betterment of the permeability would allow higher working densities, the design being modified so as to use less iron. In designing 25 cycle transformers it is necessary for magnetic purposes to use more iron than is desired, because of the low permeability of the silicon iron.

In general, a betterment of iron, without improving the permeability, can only result in lower losses and not a reduction of the cost of the transformers. In order to take full advantage of the reduced true loss, it would be necessary to increase the saturation beyond permissible values. Higher permeability and then lower losses will permit a distinct improvement in transformers.

Another line of development is improvement of the insulation so as to require less space (See Fig. 21)), permit increased temperatures and act as a heat conductor. This would allow higher copper density than is now permissible.

SPEED CONTROL OF INDUCTION MOTORS BY CASCADE CONNECTION

H. C. SPECHT

THE method of varying the speed of induction motors most generally known is that of inserting resistances in the secondary circuit. The great disadvantage of this method is that any change in load, with a given amount of resistance in the secondary circuit, results in a variation in speed, and, if the load is removed, the motor returns to its synchronous speed. Hence, for each given load and speed a different amount of resistance is required. In addition to the above disadvantages of this method, these changes in speed are accompanied by changes in efficiency; the lower the speed the lower the efficiency, and vice versa.

For the cascade of "concatenated" connection the motors are ordinarily of the type with wound secondaries; the last motor of the set may, however, be of the squirrel-cage type. The rotors of such a set are either mounted on the same shaft or connected mechanically by other means. The primary of the first motor is connected to the line circuit and its secondary winding to the primary winding of the second motor, which may be the stator or the rotor. The secondary of the last motor is either completely short-circuited or connected to an external resistance. The maximum number of speeds which can be obtained by the various connections of a cascade set consisting of two single-speed motors is *four*. Referring to Fig. I, when either motor *I* or motor *II* is running with its secondary short-circuited and its primary connected to the line, i. e., operating as a single motor, the synchronous speed obtained corresponds to that of this particular motor and equals $\frac{\text{alternations}}{\text{poles}}$ and, under load, equals $\frac{\text{alternations}}{\text{poles}} \times (1 - \text{slip})$.

If the two motors are connected in direct concatenation a speed will be obtained which is equal to $\frac{\text{alternations}}{p_1 + p_2}$ in which p_1 = number of poles of motor *I* and p_2 = number of poles of motor *II*. If the two motors are connected in differential concatenation a speed will be obtained which is equal to $\frac{\text{alternations}}{p_1 - p_2}$. For example, if motor *I* has twelve poles and motor *II* four poles and if the frequency of

the line is 25 cycles, or 3 000 alternations, the following synchron-
ous speeds will be obtained:—

1—Motor *II* running single; $\dfrac{25 \times 120}{4} = 750$ r.p.m.

2—Motors *I* and *II* in differential concatenation; $\dfrac{25 \times 120}{12-4} =$
375 r.p.m.

3—Motor *I* running single; $\dfrac{25 \times 120}{12} = 250$ r.p.m.

4—Motors *I* and *II* in direct concatenation; $\dfrac{25 \times 120}{12+4} =$
187.5 r.p.m.

Two motors are said to be connected in direct concatenation
when they have a tendency to start up in the same direction. In this
case both machines act as motors. They are said to be connected in
differential concatenation when they tend to start in opposite direc-
tions. In this case the second motor, i. e., the motor whose primary
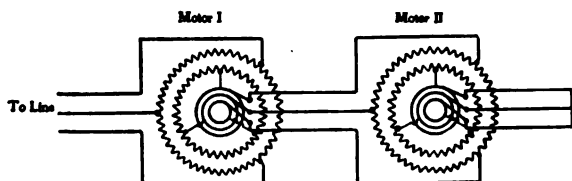
FIG. I—DIAGRAM OF CONNECTIONS OF MOTORS ARRANGED IN
DIRECT CONCATENATION

is connected to the secondary of the first motor, acts as a frequency
changer and generator. If motor *I*, having the greater number of
poles, is connected to the line, then motor *II* is producing a rotating
field in the secondary of motor *I* opposite to that of its primary. If
motor *II* is connected to the line, its effect is to boost the frequency
in the circuit connecting the two motors. This makes it possible to
obtain a speed which is higher than the speed of motor *I* running as
a single motor. In a three-speed cascade set motor *II* may have a
squirrel cage rotor if a constant resistance in the secondary is per-
missible.

In some cases more than four different speeds are required, in
which case other schemes have to be employed. For this purpose a
three-motor cascade set may first be considered. If motor *I* has 14
poles, motor *II* six poles and motor *III* four poles, by means of dif-
ferent connections the following synchronous speeds can be obtained,
operating on a 60-cycle circuit:—

1—Motor *III* running single; $\dfrac{60 \times 120}{4} = 1\ 800$ r.p.m.

2—Motor *II* running single; $\dfrac{60 \times 120}{6} = 1\ 200$ r.p.m.

3—Motor *I* and *II* in differential concatenation; $\dfrac{60 \times 120}{14-6} = 900$ r.p.m.

4—Motors *I* and *III* in differential concatenation; $\dfrac{60 \times 120}{14-4} = 720$ r. p. m.

5—Motors *I* and *II* in differential concatenation, and motors *II* and *III* in direct concatenation; $\dfrac{60 \times 120}{14-6+4} = 600$ r.p.m.

6—Motor *I* running single; $\dfrac{60 \times 120}{14} = 514$ r.p.m.

7—Motors *I* and *II* in direct and motors *II* and *III* in differential concatenation; $\dfrac{60 \times 120}{14+6-4} = 450$ r.p.m.
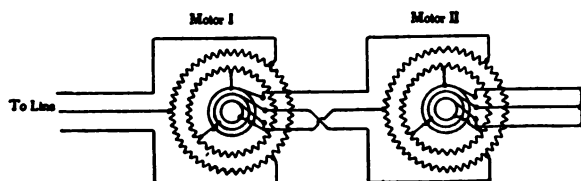
FIG. 2—DIAGRAM OF CONNECTIONS OF MOTORS ARRANGED IN
DIFFERENTIAL CONCATENATION

8—Motors *I* and *III* in direct concatenation; $\dfrac{60 \times 120}{14+4} = 400$ r.p.m.

9—Motors *I* and *II* in direct concatenation; $\dfrac{60 \times 120}{14+6} = 360$ r.p.m.

10—Motors *I*, *II* and *III* in direct concatenation; $\dfrac{60 \times 120}{14+6+4} = 300$ r.p.m.

By the above method a great number of speeds can be secured but nevertheless, such a method is not practicable. A motor set of this kind would be rather expensive and there would be difficulty in changing over from one speed to another. A much cheaper method and one superior in regard to change of speed is a cascade set consisting of one single-speed motor and one two-speed motor or consisting of two two-speed motors. For example, with motor *I* having 14 poles and motor *II* four and eight poles, the following synchron-

ous speeds can be obtained when the set is operated from a circuit
having a frequency of 60 cycles:—

    1—Motor *II* running single on four-pole connection; $\dfrac{60 \times 120}{4}$
$= 1\,800$ r.p.m.

    2—Motors *I* and *II* with eight-pole connection in differ-
ential concatenation; $\dfrac{60 \times 120}{14-8} = 1\,200$ r.p.m.

    3—Motor *II* running single on eight-pole connection;
$\dfrac{60 \times 120}{8} = 900$ r.p.m.

    4—Motors *I* and *II* with the four-pole connection in dif-
ferential concatenation; $\dfrac{60 \times 120}{14-4} = 720$ r.p.m.

    5—Motor *I* running single; $\dfrac{60 \times 120}{14}$ 514 r.p.m.

    6—Motors *I* and *II* with four-pole connection in direct con-
catenation; $\dfrac{60 \times 120}{14+4} = 400$ r.p.m.

    7—Motors *I* and *II* with eight pole connection in direct
concatenation; $\dfrac{60 \times 120}{14+8} = 327$ r. p. m.

If the cascade set were made up of two two-speed motors the
maximum number of speeds which could be obtained would be
twelve. All the foregoing combinations of speeds have been made
on the assumption that the motors are either on the same shaft or
coupled directly. In some cases and particularly in a cascade com-
bination consisting of two single-speed motors it might not be possi-
ble to obtain the exact speeds which are desired, that is, some of them
might be the ones desired while the remainder would not be. In
such a case the mechanical inter-connection of the motors might be
made through gears or chains, belts, etc., with some other ratio than
one to one. Assuming, for example, that speeds of 1 075, 940, 500
and 340 r.p.m. are desired and that the frequency of the line circuit
is 25 cycles; the closest speeds which could be obtained by a cascade
set consisting of two single-speed motors, the rotors of which were
directly connected, are 1 500, 750, 500 and 375 r. p. m. The corre-
sponding number of poles would be six in motor *I* and two in motor
II. The exact speeds which are desired could be obtained by con-
necting the two motors by means of gears or other devices giving de-
crease of speed in the ratio 2.8 to 2 and furnishing power from the
shaft of the motor with the six poles. This mechanical connection
would amount to the same thing as having both motors on the same

shaft, i. e., the cascade set would then be equivalent to a cascade set of which motor *I* has six poles and motor *II*, 2.8 poles. The no-load speeds for the different connections would then be as follows:—

1—Motor *II* running single; $\frac{3\,000}{2.8} = 1\,071$ r. p. m.

2—Motors *I* and *II* running in differential concatenation;

$$\frac{3\,000}{6-2.8} = 938 \text{ r.p.m.}$$

3—Motor *I* running single; $\frac{3\,000}{6} = 500$ r.p.m.

4—Motors *I* and *II* running in direct concatenation;

$$\frac{3\,000}{6+2.8} = 341 \text{ r.p.m.}$$

The different schemes for possible speed combinations in a cascade set having been described, the performances at the different speeds will be considered. Two motors connected either in direct or differential concatenation can be considered, electrically, as if they were connected in series, that is, with the stators and rotors of both motors designed for the same voltage, approximately the same current will flow through each member. In case of lower power-factor the current in each member will differ somewhat, the current in the primary of motor *I* will be the highest and that of its secondary, which at the same time is the primary current in motor *II*, will be lower and finally the secondary current of motor *II* will be the lowest. The lower the power-factor, the greater will be the difference between the currents. The conclusion to be drawn from the above is that the total magnetizing current for motors in concatenated connection is equal to the sum of the magnetizing current of the individual motors whether they be connected in direct or differential concatenation, i. e., the total magnetizing current is the same; and, furthermore, the reactance or leakage with the motors connected in either direct or differential concatenation is equal to the sum of the reactances of the separate motors. From these two facts it is clear that the power-factor and maximum output is lower with concatenated operation than by having motors operating independently. Therefore, a cascade set is generally more expensive than one single-speed or two-speed motor, and for this reason the application of cascade sets is somewhat limited; but, nevertheless, in many cases the required number of speeds cannot be obtained by other means without complications and without running the cost higher than, or at least as high as, that of the cascade set. Further, in a good many cases

the conditions of operation are of such a character that the cascade set is superior to the other schemes.

As a rule the operation and control of the cascade set is simple and safe. For example, several speeds can be obtained without breaking the main circuits. This has a great advantage over any multi-speed motor in which the changes in speed require opening of the main circuit before the new connection can be made, unless choke coils or other complications are employed. Particularly on motors of large capacity or of high voltage the opening and closing of the main circuits is very undesirable.

The diagram, Fig. 3, shows the connections of a cascade set in which two speeds can be obtained in a very simple manner without breaking any of the main circuits. The full lines represent the connections when the motors are operating at low speed, i. e., in direct
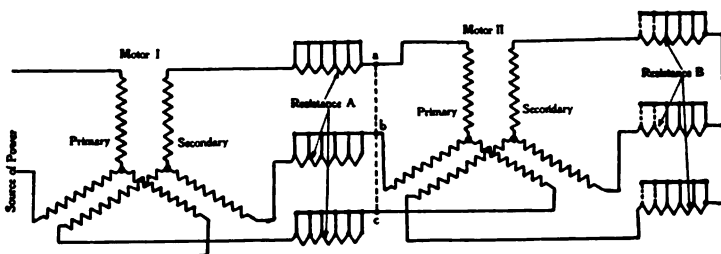
FIG. 3

concatenation, with some resistance in the secondary circuit of motor *II*. When the motor set is to be run at a higher speed the resistance at *B* will be short-circuited; the short-circuiting connections on resistance *A* will be opened step by step; the points *a, b* and *c* will be short-circuited, and finally resistance *A* will be short-circuited to the point giving the desired speed. The change from high speed to the low speed is accomplished by reversing the above operation. It is obvious that with this method of control the changing from one speed to another can be done in a very smooth and safe way without opening any of the main circuits. It is possible to obtain a greater number of speeds without adding greatly to the complication of the connections and still keep the main circuits closed throughout.

In order to obtain some idea of the simplicity of the control of the different combination in a cascade set, the number of motor leads which are required for three-phase cascade sets consisting of two motors, is given below:—

1—Cascade set in which motor *I* has a wound rotor and motor *II* a squirrel cage rotor; nine leads are required and a maximum of four speeds is possible.

2—Cascade set in which each motor has a wound rotor; 12 leads are required and a maximum of four speeds is possible.

3—Cascade set in which motor *I* is a single-speed wound-rotor type machine and motor *II* is a two-speed squirrel cage motor; 12 leads are required and a maximum of seven speeds is possible.

4—Cascade set in which each motor has a wound rotor and motor *II* is a two-speed motor; 18 leads are required and a maximum of seven speeds is possible.

5—Cascade set in which motor *I* is a two-speed motor with wound rotor and motor *II* is a two-speed squirrel cage motor; 18 leads are required and a maximum of 12 speeds is possible.

6—Cascade set in which each motor is a two-speed motor with wound rotor; 24 leads are required and a maximum of 12 speeds is possible.

As compared with the above a single multispeed motor requires leads as follows* :—

1—Ordinary two-speed motor with squirrel cage rotor; pole ratio 1 :2; at least six leads are required and for a motor with wound rotor twice as many.

2—Four-speed motor with squirrel cage rotor; 12 leads or more are required and for a motor with wound rotor, at least 24 leads are required.

3—Six-speed motor with squirrel cage rotor, having 4, 6, 8, 12, 16, or 24 poles; at least 48 leads are required and for a motor with a wound rotor, 95 leads. The number of leads increases with the number of poles.

The above figures show that the multispeed motor requires a much more complicated controller or switching device than the cascade set.

In addition to the foregoing it may be of interest to discuss the torque of cascade sets, both initial and running. The amount of total torque which can be obtained from a cascade set at the same real input and primary losses is equal to that of a single

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*See "Neuer seches-stufiger Motor und die Verwendung der Stufen-motoren zum Antrieb von Stoffdruckmaschinen," by O. Knopfli, in *Elektrische Fraftbetriebe und Bahnen* of February 4 and 13, 1909.

motor with the same synchronous speed, i. e., the torque for cascade sets may be expressed as follows:

Torque (in lbs. at one foot radius) $= 32.7 \times$ (real input — prim. losses) $\times \frac{\text{poles}}{\text{cycles}}$.

For example, if the motors of a cascade set are starting or running in direct concatenation, Lbs. torque at one foot radius $= 32.7 \times$ (real input — prim. losses) $\times \frac{p_1 + p_2}{\text{cycles}}$. When motors are connected in differential concatenation, Lbs. torque at one ft. radius $= 32.7 \times$ (real input — prim. losses) $\times \frac{p_1 - p_2}{\text{cycles}}$. This shows that for the least input of energy the highest torque is obtained when motors are connected in direct concatenation and this connection is therefore most suitable for high starting torque with the least amount of energy.

The torque developed by each motor of a cascade connection is proportional approximately to the ratio of its number of poles to the total number of poles of the set, multiplied by the total torque. Thus, with two motors connected in direct concatenation, one having ten poles and the other four poles, the torque developed by the first motor will be $\frac{10}{14}$ of the total torque of the set and that of the second motor will be $\frac{4}{14}$. With differential concatenation, the torque of each motor will be the same but as they act in opposition, the total resultant torque will be proportional to the ratio of the difference of the number of poles. Thus, with the motors considered above, the total torque with differential concatenation would be equal to $\frac{10 - 4}{14} = \frac{3}{7}$ of the torque developed by the motors when connected in direct concatenation.

The differential concatenation gives, in general, the lowest starting torque and, moreover, if the motor having the greater number of poles is connected to the line, the motor set will not come up to its synchronous speed by itself. It will reach the synchronous speed of the single motor which is connected to the line and will not exceed this speed. Therefore it will be necessary to connect the motor having the smaller number of poles to the line and, when the set has nearly reached full speed value for differential connection, to switch over to the normal connection, i. e., having the motor with the greater number of poles connected to the line.

It should be mentioned that, if neither of the two motors has less number of poles than that given by the difference between

the number of poles of the two machines, the speed of the differ-
ential concatenation cannot be obtained without the set being
speeded up by separate drive or other auxiliary means; i. e., the
synchronous speed of the single motor which is connected to the
line should be higher than the speed which is to be obtained by dif-
ferential concatenation. In most cases it is not advisable to leave
the motor having the smaller number of poles on the line because
the frequency in the circuit connecting the motors will be of higher
magnitude. The total iron losses of the set would, therefore, be
considerably greater, causing a drop in the efficiency and also caus-
ing a higher temperature rise. In a case where a higher iron loss
is not objectionable, the motor with the smaller number of poles
may remain on the line.

Since the practical application of cascade sets involves so
many different conditions, this phase of the subject has been left
for a future article.*

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*For further data and mathematical discussion on cascade operation, see
paper by the author on "Induction Motors for Multispeed Service with Par-
ticular Reference to Cascade Operation," Proc., A. I. E. E., June, 1908, p. 791.

METER AND RELAY CONNECTIONS (Concluded)

RELAYS ADAPTED TO SPECIAL USES

HAROLD W. BROWN

O F the various kinds of relays used in ordinary service, each has certain functions that it is especially adapted to perform, but there are some special duties that may be assigned to relays that were originally intended for other service. The following examples will be suggestive of the numerous combinations that may be utilized to obtain various results.

PROTECTION AGAINST SHORT-CIRCUITS AND GROUNDS

Overload relays connected in the ordinary way operate at a predetermined overload; but this does not fully protect against short-circuits because a partial short-circuit may not take any more current than the normal load. By the use of an extra series transformer, however, connections may be made so that the action of the relay depends not on the total current transmitted, but on the current that is *lost* between the two series transformers. These transformers may have their secondary circuits connected either so that their currents are opposed to each other, or so that both currents tend to flow in the same direction. Figs. 1 and 2 illustrate the two methods of connection applied to a single-phase circuit.

Protection of Power Transformers—In Fig. 1 the two series transformers *A* and *B* tend to send currents in opposite directions. These series transformers are on opposite sides of the power transformer, and their ratios of transformation are such that each tends to have the same secondary current under the normal operating conditions. If the transformers are designed so that under these conditions the e.m.f.'s across the secondaries are equal, no current flows in the secondary circuit*; but if there is a short-circuit or a partial short-circuit in the power transformer the current in its secondary has the wrong ratio to that in its primary. As a result, one of the series transformers overpowers the other and sends a current through the relay, thus opening the circuit breaker.†

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*When no current flows in the secondary, the e.m.f. is the same as if the secondary were open, so that the two series transformers must be designed to have equal secondary e.m.f.'s on open circuit.

†This method of protection was referred to in an article by Mr. M. C. Rypinski in the JOURNAL for January, 1908, p. 42.

The secondary connections of the series transformers in Fig. 2 are different from those in Fig. 1 in that the transformers are not opposing each other and the relay is not directly in series with the two transformers, but is connected between the two lines that join them. There is no necessity that the open-circuit e.m.f.'s of the two transformers be equal, because the transformers never have the equivalent of an open circuit. If the currents in *H* and *L* are in the wrong proportion, one of the series transformers has a larger secondary current than the other, and this excess current flows through the relay and thus operates the trip coil.

The advantages of the arrangement shown in Fig. 1 over that shown in Fig. 2 are: (a)—that there is no copper loss in the line or transformers, because no current
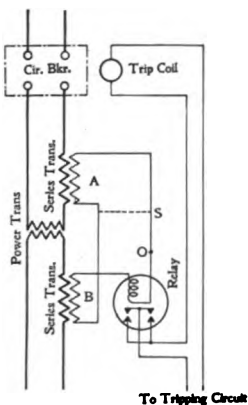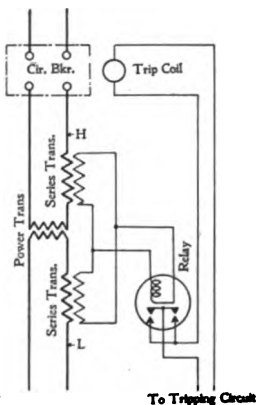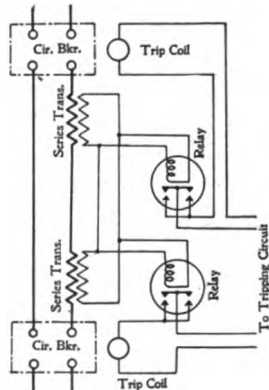
FIG. 1   FIG. 2   FIG. 3

is flowing, and (b)—that there is no danger of failure to operate on account of short-circuits between the secondary lines, for such a short-circuit, at *S*, for example, would cause the current from one transformer to flow through the relay, so that it would operate. The disadvantages of Fig. 1 in favor of Fig. 2 are (a)—that the iron loss in Fig. 1 is high because the iron is saturated when the current flows only in the primary; (b)—that the relay will fail to operate if the secondary circuit is broken, for if there is an open circuit, at *O*, for example, no current flows in the secondary circuit; (c)—that the e.m.f. between the lines interconnecting the series transformers may be dangerously high, because of the virtual open circuit; (d)—that if the two series transformers are not identical in their construction, or if the iron in one ages more than that in the other, their e.m.f.'s on virtual open cir-

cuit may not be the same, so that a current may circulate through the relay and make it operate even if there is no short-circuit.

In either Fig 1 or Fig. 2, if the line is liable to be connected to a source of power on each side of the power transformer, circuit breakers must be inserted on both sides of the power transformer so that in case of break-down the transformer will be entirely disconnected from both circuits. Both of these circuit breakers may be operated from the one relay, the trip coils for this purpose being connected in series across the tripping circuit.

Protection of Transmission Lines—A transmission line may be protected against short-circuit in the same manner as that outlined for the protection of transformers. The two series transformers, one at each end of the transmission line, are connected by means of an auxiliary circuit according to one of the methods shown in Figs. 1 and 2 and operate in the same manner as when they protect power transformers. If it is necessary to have a circuit breaker at each end of the transmission line, two relays may be provided. When connected as in Fig. 3, i. e., with the transformers operating in series with one another, the resistance of the circuit through the relay must be enough higher than that of the secondary circuit from one series transformer to the other to prevent the relay from being operated by current circulating from the adjacent transformer through the relay and back to the transformer without flowing through the remainder of the secondary circuit, which includes auxiliary line wires. If the relay circuit resistance were too low the relay would operate whenever there was current flowing in the series transformer whether there were a short-circuit or not.

Whenever a ground occurs, allowing a leakage current to flow, the effect, of course, is that of a short-circuit; thus this arrangement protects against such grounds as well as against short-circuits between lines. Of course, if a circuit is grounded at only one point, no appreciable leakage current flows. This arrangement would not protect against such a ground.

This method of line protection has been applied with success to several important transmission systems both in this country and abroad. Its application is not confined to lines of short length as, by the use of series transformers of such ratio as to give small full-load secondary current (and relays of corresponding design), the power lost in the auxiliary line may be reduced to a minimum. The resistance of the local relay circuits may be adjusted to the de-

sired value by the use of external resistance. The points of advantage and disadvantage of the two methods of connection considered with reference to Figs. 1 and 2 are likewise applicable to this case. The use of special series transformers in connection with this system of protection prevents the grouping of instruments on the same secondary circuits, unless the instruments have special windings.

Application to Polyphase Circuits—Polyphase connections may be arranged for the protection of banks of transformers or polyphase transmission lines on the same principles as those outlined above with reference to single-phase circuits. The three-phase connections shown in Fig. 4 correspond in principle to those of Fig. 2. The two sets of series transformers are Z-connected in order to protect all three of the power transformers. Unequal currents in cor-
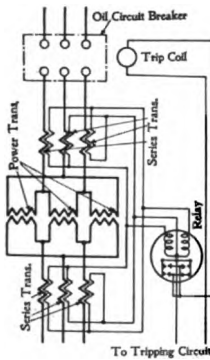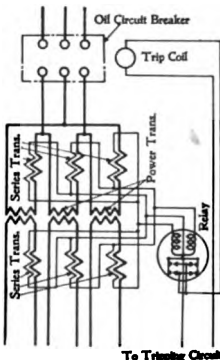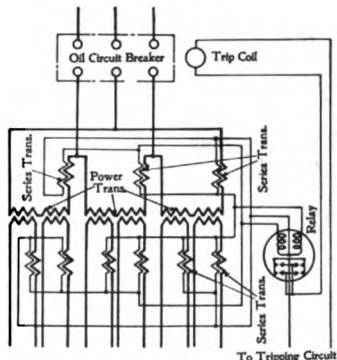
FIG. 4   FIG. 5   FIG. 6

responding transformers of the two sets, such as would occur in case of a short-circuit or ground, would result in a flow of current in one or both of the relay circuits, causing it to operate and trip the circuit breaker. Fig. 5 shows the same principle adapted to a six-phase diametrically-connected circuit. The series transformers are delta-connected in this case, but could also be Z-connected, as the effect of trouble on the power circuits would be the same on the series transformer secondary circuits to which the relay is connected. Fig. 6 shows the application to a six-phase double delta-connected circuit. This is similar to the connections for three-phase, but six series transformers are required on the six-phase side. The sum of the currents in two of the six-phase lines is equivalent to one current on the three-phase side. The transformers on the three-phase circuit are Z-connected in pairs.

They could also be delta-connected on the three-phase side, if they were delta-connected in pairs on the six-phase side.

PROTECTION AGAINST BOTH OVERLOAD AND SHORT-CIRCUIT

If a relay for series tripping* instead of shunt tripping is used, it is possible to protect against both overload and short-circuit on lines or transformers. Fig. 7 illustrates an arrangement offering such protection to a three-phase system. The series transformers in each set are Z-connected. The currents from the series transformers on lines *A* and *B* flow through the relays numbered *1*, and the currents from those on *B* and *C* flow through the relays numbered *2*. So long as a nor-

FIG. 7—OVERLOAD INVERSE TIME LIMIT RELAYS PROTECTING AGAINST OVERLOAD, AND AGAINST BREAK-DOWN OF POWER TRANSFORMERS ·

In case of overload the relays act with a time element; but, in case of break-down of power transformers, the trip coils act instantaneously, independent of the relays.

mal current flows and no short-circuit exists, the currents from the transformers at the left flow through the relays at the left. The line resistance must be small enough compared with the resisances of trip coil circuits so that the small currents normally shunted through the trip coils will not open the circuit breakers. If the secondary currents are unequal in corresponding transformers on the right and left, due to short-circuit on the line or on the power transformers, the differential currents flow through the trip coils and open the circuit breakers. In case of overload on any line the relay contact is opened, and the current flows through the trip coil connected to that relay, thus operating the circuit breakers. If the relays have a time element in their operation, the protection against overload has the time element, but the protection against short-circuit is instantaneous in any case, because the action is then dependent only on the trip coil and not on the relay. The arrangement of Fig. 7 may be modified to adapt it to single-phase or two-phase circuits.

Two instead of four relays may be used, if each relay has two

*See the JOURNAL for July, 1908, p. 412, Figs. 11, 12 and 13.

trip coils connected to it in series, one on each circuit breaker. This necessitates the use of two extra lines between circuit breakers; hence, if the circuit breakers are far distant from each other, it is better to have four relays.

RELAY FOR INSERTING RESISTANCE

A series trip relay may be connected as in Fig. 8 to switch resistance in and out of a circuit such as the field circuit of a generator or booster; the relay operating in case the current becomes excessive. The capacity of the relay must be sufficient for the entire current unless an auxiliary relay is used. The action of this relay may be either instantaneous or with a time element.

REVERSE CURRENT RELAYS WITHOUT OVERLOAD FEATURE

A method for eliminating the overload feature from an alternating-current overload and reverse current relay has been described in a previous article in the JOURNAL.*
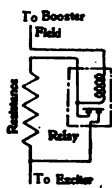
FIG. 8

OTHER USES OF RELAYS

The difference in principle between the meter and the relay is that a meter indicates a measurement, and a relay performs an operation. A relay may be made to correspond to nearly every type of meter, in the manner that an overload relay corresponds to an ammeter, and an over-voltage relay to a voltmeter. For example, relays may be variously connected to operate on any kind of circuit in case of (a)—grounding one line; (b)—unbalanced current, or (c)—unbalanced voltage; but such use of relays is not common.

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*See "A New System of Sub-Station Relays for Incoming Transmission Lines," by Mr. Paul MacGahan, in the JOURNAL for November, 1908, p. 638.

EXPERIENCE ON THE ROAD

POLYPHASE WATTMETER CONNECTIONS

M. H. RODDA

ONE of the troubles which have been encountered more or less frequently in the writer's experience comes under the heading "Polyphase Wattmeter Connections." The case is usually somewhat as follows:—

A small manufacturing concern will have one or more induction motors installed by the local electric power company. When the motor is first started it frequently happens that the only available load is the line shaft or the motor itself. The power-factor of such a load is often very low, in fact much below 50 percent. The local meter man knows that a single-phase wattmeter should be installed with connections made so that the disc will revolve in the positive direction. When he comes to connect the polyphase meter he adopts the same practice. Each side is connected singly so that the disc will revolve in the positive direction. This check for connection is correct under certain conditions of load and power-factor. If so connected when the motor or motors are operating at a power-factor below 50 percent there will probably be some trouble. Under light loads the meter will read too fast and under heavy loads, too slow. The local power company soon finds that its charge against the manufacturing concern for power seems much too small considering the amount of work being done. At once the correctness of the meter is questioned and an investigation follows.

As the motor is now connected to its regular load, it is found, by disconnecting one of the elements of the meter at a time and noting the direction of the rotation of the disc, that it revolves backward with one connection and forward with the other, the number of revolutions in one case being somewhat less than in the other. The resulting speed, therefore, when both elements are connected, is the difference and not the sum of their individual speeds.

The correct connections of a polyphase wattmeter on a three-phase circuit depend on the power-factor of the load and there is a well-known rule for connecting, which reads somewhat as follows:—When the power-factor is below 50 percent connect that element of the meter, which gives the least number of disc revolu-

tions in a given time, so that the disc will rotate in the reverse direction. With the other phase connected to give positive rotation of the disc, the result will be positive rotation of the disc when both phases are connected.

The usual method of connecting a polyphase wattmeter is shown in Fig. 1, in which W_1 and W_2 represent the two elements of the meter. Each element is practically a single-phase wattmeter and each measures a part of the power in such a way that the sum of the two is the total power. The element W_1 is connected in the circuit AC, just as it would be if AC were a single-phase circuit, except that the series coil carries not only the current in phase AC, but also that in phase AB, as both currents are combined in the conductor A giving a resultant current, in a symmetrically loaded circuit. differing in phase by 30 degrees from that in phase AC.
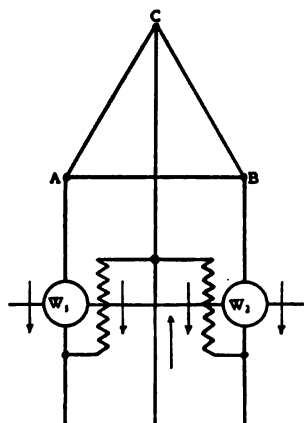
Likewise in the element W_2, the resultant .current in the series coil of the meter is displaced in phase 30 degrees from the current in the phase BC. Hence the two elements of the meter act as single-phase wattmeters in which the third phase AB causes displacements of the currents in the series coils of 30 degrees. In one case the displacement is leading, in the other it is lagging. With 100 percent power-factor the current in one series coil is 30 degrees behind the e. m. f. impressed on the shunt coil and in

FIG. I.

the other it is 30 degrees in advance of the current in the corresponding shunt coil. The torque produced is the same in each element. With 90 percent power-factor, corresponding to a lag of current of nearly 30 degrees behind that at 100 percent power-factor, the current in one meter element instead of lagging 30 degrees is retarded nearly 60 degrees, and in the other element the current does not lead the e. m. f. by 30 degrees but is nearly in phase with it. Hence the torque on one element is reduced while that on the other is increased. With 50 percent power-factor, corresponding to 60 degrees lag, one element carries current which lags (30 + 60) or 90 degrees behind its e. m..f., while the other current is changed from 30 degrees leading to 30 degrees lagging. Hence one element has zero torque

and the other has the same torque that it would have on the same
current at 100 percent power-factor. At 50 percent power-factor
the indication is reduced not by reducing the torque on each ele-
ment by half, but by reducing that on one element to zero. If the
lag on a three-phase circuit is greater than 60 degrees, as when the
power-factor is below 50 percent, then the lag in one element is
more than 90 degrees and thus the torque is reversed in direction
and this element, if free to move, would run backwards. As the
torque of the other element is greater, it overbalances the ten-
dency towards reversal, with the result that the motion is positive
and the torque is in all cases proportional to the total power. The
values and relative position of the voltages and currents may be
illustrated by the use of the vector notation:*
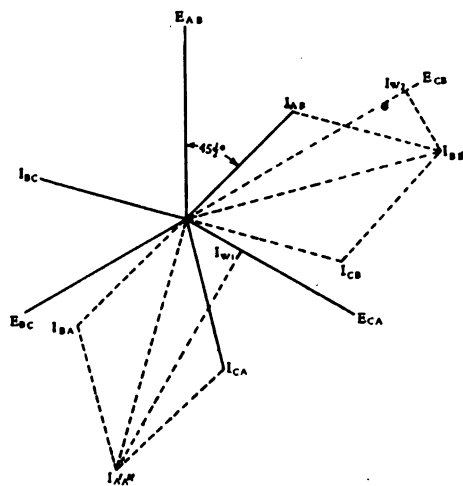
FIG. 2.

For example: As-
sume a three-phase
load of 21 kw at 200
volts, under conditions
of 70, 50 and 30 per-
cent power-factor. The
various currents are
calculated as follows:
For a balanced three-
phase circuit the pow-
er in each phase =
kw ÷ 3 = (volt-am-
peres × power-factor)
÷ 3 × 1 000, or am-
peres = watts ÷ 3 ×
volts × power-factor.
For 70 percent power-

factor the current per phase is 21 000 ÷ (3 × 200 × 0.7) = 50
amperes per phase. Similarly for 50 percent power-factor the cur-
rent per phase is 70 amperes and for 30 percent power-factor the
current per phase is 116.6 amperes.

In Fig. 2, with 70 percent power-factor, E_{AB}, E_{CA}, and E_{BC}
are the three voltage vectors. I_{AB}, I_{CA} and I_{BC} are plotted as lag-
ging behind their respective voltages an angle whose cosine is 0.7
or about 45.5 degrees. The current in the series coils of W_1 (Fig.
1) will be the resultant of the currents passing from C to A and
from B to A. These two currents are shown in Fig. 2 as I_{CA} and

*Described by Mr. Chas. H. Porter in the JOURNAL for September, 1907.

IBA, and their resultant indicated as IA′A″. The voltage coil of W_1 is connected across C and A. The current IA′A″ makes an angle of less than 90 degrees with its voltage ECA. A perpendicular from IA′A″ to ECA falls at the point IW_1, a distance representing 45 amperes from the center of the vectors, thus IW_1 equals the power current or current in phase with the voltage.

In W_2 the current to be measured is that which flows from A to B and from C to B. Carrying out the same plan as for W_1, IB′B″ is the resultant current and should be measured as shown by the arrows in Fig. 1, i. e., from C to B. A perpendicular from IB′B″ to ECB falls at the point IW_2. IW_2 scales 60 amperes. A check on this work is obtained by the fact that $45 + 60 = 105$, and $105 \times 200 = 21$ kw, the load assumed. As the phase displacements between the voltage and the current in both cases are less than 90 degrees, the consine is positive and the disc should revolve in a positive direction with either or both elements connected.
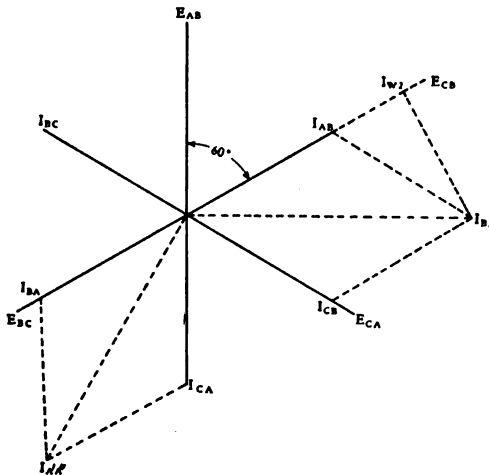
FIG. 3.

When the power-factor is 50 percent., i. e., with the current lagging 60 degrees behind the voltage, as in Fig. 3, the line IA′A″ makes an angle of exactly 90 degrees with ECA. Since the cosine of 90 degrees is zero, there will be no tendency of the disc to revolve in either direction even with 200 volts impressed on the voltage coil and a current equal to IA′A″ in the series coil. Considering the other element W_2, IW_2 scales 105 amperes which multiplied by 200 volts give 21 kw. Therefore, the element W_2, will record the total power of the load. Under these conditions (which seldom exist), it is difficult to determine the correct connections of W_1.

On passing the 50 percent power-factor line, the current in W_1 swings into the second quadrant (being greater than 90 degrees) and is negative and W_1 should be so connected that the disc will revolve in the negative direction. By the same method as before,

IW_1 scales 45 amperes and IW_2, 150 amperes. Subtracting the current in W_1 from that in W_2, $150 - 45 = 105$ amperes: $105 \times 200 = 21$ kw. If the disc had been made to revolve in the positive direction for both phases, the result would be $45 + 150 = 195$ amperes. $195 \times 200 = 39$ kw, an incorrect result.

By the use of the method outlined above, the shifting conditions with changing power-factors can readily be followed.

In connecting up a polyphase wattmeter the following method may be used as a check on the connections:—1—The power-factor may be determined as follows: Connect the current coils of the two elements of the wattmeter in two of the main lines at W_1 and W_2, leading to the load *ABC* to be measured, as shown in Fig 1, but leaving the shunt coils disconnected. The shunt terminals of element W_1 should then be connected across *AC* and the direction of the rotation of the meter disc noted. Then disconnect at *C* and connect at *B*. If the disc then revolves in the opposite direction, the power-factor is below 50 percent. If it revolves in the same direction, tests should be made with the element W_2 as was done with
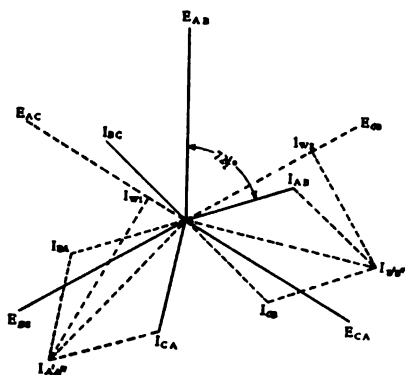
FIG. 4

W_1, placing the loose voltage terminal first on *C* and then on *A*. If with these connections the same direction of rotation is observed, the power-factor is above 50 percent; if in the opposite direction, the power-factor is below 50 percent. If the power-factor is 50 percent, rotation will take place with one connection of W_1 or W_2 and not with the other. The reasons for the above may be seen by referring to the vector diagrams, Figs. 2, 3 and 4, and remembering that a given positive rotation will be reversed as soon as the phase angle between the voltage and current exceeds 90 degrees. 2—Having determined the power-factor, within the necessary limits, the final connections should be made so that each element will tend to give positive rotation, if the power-factor is above 50 percent. For power-factors below 50 percent the rule already given applies. If the tests should indicate a power-factor of exactly 50 percent, the load should be changed until a suitable power-factor is obtained. If series and shunt transformers are used to reduce the current and

voltage, the same principles apply as for direct connection. The extra voltage connection may be obtained by connecting the two shunt transformers in V. If it is necessary to reverse the direction of rotation of an element to secure positive rotation, this may be accomplished by reversing the connections to either the shunt or the series coils.

TWO-PHASE—THREE-PHASE TRANSFORMATION USING STANDARD TRANSFORMERS
SETH B. SMITH AND E. C. STONE

IT was desired to obtain two-phase power at 300 volts. The only available source of supply was three-phase at 2 300 volts, and the only available apparatus was standard transformers having ratios of 2 300/230-115 volts. The desired transformation was obtained by the method of connection shown in Fig. 1. The primaries of three transformers of equal capacity were connected to the three-phase line in ordinary delta. The secondary voltage relations are shown in Fig. 2. One of the two phases is 98 degrees instead of 90 degrees from the other, but this does not interfere with the opera-
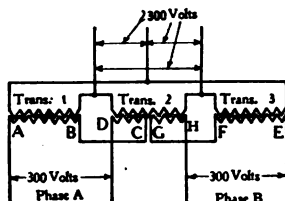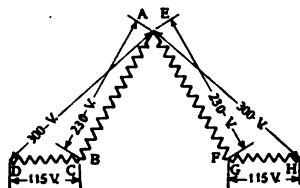
FIG. 1   FIG. 2

tion of two-phase motors, nor does it seriously distort the three-phase primary side. Transformers connected in this way will safely carry about 90 percent of their combined rated load. On account of the 98 degree relation of the two phases, the three-phase primary currents are not exactly 120 degrees apart and the current in one line is only 80 percent of that in the other two.

If a three-wire, two-phase system is desired, leads *A* and *E*, Fig. 1, may be connected together and the common wire taken from that point. Transformers *1* and *3* are now connected in open delta, and three-phase current at 230 volts may be taken from *A, B* and *EF* in addition to the two-phase load. The combined load, however, in this case should not exceed 85 per cent of the rating of the transformers.

If taps on each half of transformer *2* were available, each one being 13.4 percent of the whole winding, perfectly balanced two-phase e. m. f.'s would be obtained. This method of connection has the advantage that two-phase current may be obtained from a three-phase circuit by the use of three ordinary standard single-phase transformers or a standard three-phase transformer.

A TWO-PHASE—THREE-PHASE EMERGENCY CONNECTION

D. C. McKEEHAN

THE several articles which have recently appeared in the JOURNAL, giving standard and special methods of obtaining two-phase—three-phase transformation have been both interesting and valuable. The method represented in Fig. 1 was recently devised to restore service on a system using the standard method of two-phase—three-phase transformation described by Mr. Stone in the JOURNAL for October, 1908, after one of the 25 kw transformers had burned out. It was necessary to get power to

Three-Phase Primary

86.6%

10 Kilowatts   10 Kilowatts   25 Kilowatts

220 Volts   220 Volts
Phase A   Phase B

Two Phase Secondary
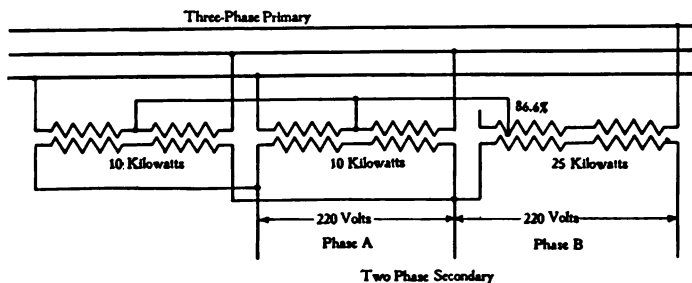
FIG. 1

the two-phase circuit supplied by the transformer bank as soon as possible. Having two spare 10 kw transformers, their primaries and secondaries were connected up in multiple, the middle taps on the high tension sides being joined together, as shown, and connected to the 86.6 percent tap of the "teaser" transformer. With this arrangement the phases were found to be practically balanced and operated in this way quite satisfactorily for months.

THE JOURNAL QUESTION BOX

271—TROUBLE WITH STARTING MOTOR FOR ROTARY CONVERTER—In a local station there has recently been erected a 2 000 kw, 60-cycle, six-phase rotary converter. The weight of the armature is 35 tons and the speed (synchronous) is 225 r.p.m. On the shaft is a 200 hp (nominal) squirrel cage induction motor. At a line voltage of 360 volts this motor draws 900 to 1 200 amperes; the rotor gets red hot after about 15 seconds, and the steel studs connecting the conductors to the short-circuiting rings split; yet the rotor refuses to move. The rush of current is sufficient to cause the lights of the whole city to drop five to eight volts. If the rotary converter is started on the direct-current side and the starting motor circuit is connected after the armature has attained some speed, everything is all right. If the voltage is reduced (in order to reduce the rush of current), the torque, which is already insufficient, is of course reduced as the square of the voltage. Would it not be more satisfactory to replace the squirrel-cage rotor by a slip ring, phase - wound rotor which could be operated by means of a variable resistance of perhaps two or three steps?

I. L. K-R.

The static friction in the bearings of a large machine such as that under consideration is very large compared with the friction after the machine is in motion and the film of oil has been established between the journal and the bearing surface. A very large torque is therefore required in the starting motor, sufficient to overcome this static friction, which is not required after the converter has turned over. It is necessary to be able to dissipate in the rotor winding, or in circuits connected with it, an amount of energy equivalent to that required to start the rotating parts of the machine. As the squirrel-cage rotor of an induction motor of reasonable size cannot have sufficient capacity to dissipate this amount of energy, it is necessary, as suggested in the question, to provide a wound-type of rotor, equipped with slip rings, for a converter of this large size. The necessary heat dissipation is then transferred to an external resistance which may be designed sufficiently large for this purpose. This resistance is of course adjustable and may be short-circuited when the starting motor reaches full speed, whereupon the motor has practically the same operating characteristics as the squirrel-cage type of rotor. See characteristic curves of wound secondary induction motors in the JOURNAL for July, 1908, p. 383   F. D. N.

272—RE-WINDING INDUCTION MOTOR—The rotor of a 5 hp, six-pole, three-phase motor was entirely burnt out. It was originally wound with two conductors of No. 10 wire and was Y-connected. In rewinding the motor four conductors of No. 2 solid copper wire were used. These were soldered into heavy cast copper rings milled out to receive them. The motor now starts up properly, but the stator winding quickly overheats and begins to smoke in less than a minute after starting. The

stator windings are Y-connected. They have not been disturbed and are, in fact, in good condition. Is the overheating due to the use of the larger wires in the stator? What should be done to remedy the trouble?   H. P. W.

With the meagre data given, it is difficult to judge as to the cause of the overheating of the stator winding. It may be due to the fact that the low secondary resistance obtained with the squirrel-cage winding which has been substituted for the resistance-wound secondary allows an abnormal starting current to flow in the primary of sufficient magnitude to quickly overheat that winding. If this is the cause, the abnormal heating should disappear shortly after the motor has attained its speed. The trouble may be due to the fact that, when the secondary burned out, the heat produced caused the primary insulation to be damaged and to break down inside the iron where it cannot be inspected, the present heating being due to a short-circuit in the primary resulting therefrom. In either case, we would suggest that the trouble be investigated by starting up the motor without load, *i. e.*, with the belt off, and allowing it to run for a few minutes. If the primary cools off after the motor comes up to speed, this would be an indication of the first trouble mentioned above. If the stator continues to heat, it would indicate the second condition. In case the first condition proves to be the cause of the trouble it could be remedied by starting the motor with reduced voltage, *e. g.*, by means of an autostarter; or, otherwise, the difficulty could be overcome by changing the secondary winding. Again if the cross-section of the end rings will allow it might be possible to increase the secondary resistance sufficiently by sawing small slots in these rings, between the bars; but, if this is done, care should be taken to leave sufficient cross-section to withstand the mechanical stresses at full speed, and the cuts should be made of uniform depth. It is also advisable to make the cuts in one ring only, at first, and then if the trouble is not entirely overcome, to slot the other ring. It is better to procure the ex-

act results desired by more than one cutting than to reduce the cross-section more than is necessary. M. W. B.

273—CHANGING 120-VOLT GENERATOR TO 220-VOLT MOTOR—We have a 700 r.p.m., 120-volt compound - wound generator which we intend to rewind for service as a 220-volt motor. Please indicate the necessary changes.   W. H. W.

In order to maintain constant direction of rotation, it is necessary to reverse the polarity of the machine; the simplest way in this case being to reverse the armature leads where they are connected to the brush rigging (that is, inside the series field connection). If a simple shunt wound motor is desired, the series field should be entirely disconnected. The shunt may be adapted to the higher voltage by introducing an external resistance in series with it of approximately the same effective resistance as that of the field. (In this connection, see No. 29 in the February '08 JOURNAL.) This will introduce a slight loss which can be avoided only by rewinding the field with wire of one-half the size and about the same total weight. As noted in No. 29, the armature may be used without rewinding if the increased voltage between commutator bars does not prove to be too great to give satisfactory commutation. In this connection, it may be found of assistance to bevel the brushes a little in order to decrease their thickness. If the armature is used without rewinding, the speed of the machine as a motor will be considerably increased by the higher impressed voltage because, in order to give a corresponding counter e.m.f., the speed must be increased in proportion. If the armature is to be rewound, wire of one-half the size and approximately the same total weight should be used. This will give about twice the number of turns per coil which, with twice the resistance and therefore one-half the current, will give the same number of ampere-turns in the armature, but with twice the counter e.m.f. at the given speed. Thus the speed would remain approximately the same as with the original winding at the lower voltage.   F. A. R.

274—500-Volt Motor on 230 Volts
—What changes are necessary
to adapt a 500-volt, two-pole,
direct-current motor for use
on a 230-volt circuit to give
full capacity? What changes
would be required if it is to
give full capacity at one-half
speed? If the armature has
to be re-wound, what changes
should be made? The ca-
pacity is 5 hp. the full load
armature current being 9 am-
peres, and the normal speed of
the motor when operated at
500 volts is 1 700 r.p.m. There
are 31 armature slots, the coils
being arranged in two groups
of two layers each. No. 16
wire is used, the leads to the
commutator being connected
alternately to the left and
right. The commutator has 62
segments.   H. P.

To adapt the motor to 230 volts
with normal full-load capacity, the
armature should be re-wound with
wire of double the cross-section of
that used at present and half the
number of turns per coil. This may
be accomplished by using the same
size of wire, two in parallel, or by
using wire three sizes larger. To
adapt the field to the lower voltage
the shunt coils could be connected in
parallel or re-wound with half the
number of turns of wire three sizes
larger. The brush section should be
doubled to take care of the cor-
respondingly large current. This of
course means to obtain half speed
without a corresponding reduction in
capacity. One-half capacity and ap-
proximately half speed may be ob-
tained by simply paralleling the field
coils and operating the armature, as
wound at present, on the 230-volt
circuit.   F. A. R.

275—Calculation of Size of Wire
—2 000, 16 c-p lamps, 60 watts
per lamp, are to be operated at
a point 8 000 feet from the
generating station. The pri-
mary voltage of the trans-
former is about 2 080, the sec-
ondary voltage being 110. The
allowable line loss is ten per-
cent in the primary circuit and
two percent in the low volt-
age distributing circuit. The
transformer efficiency is 95
percent. I find the following
formula for the calculation of
the size of wire, in circ. mils.,
required for the transmission
line, but it does not take into
consideration the efficiency of
the transformer:—(D x W)÷
(P x E²) x 1 500 = circ., mils.,
in which D = length of line
from the power house to step-
down transformers, W = total
watts delivered, P = percent
loss in the line, E = the pri-
mary voltage at the trans-
former, 1 500 being the con-
stant used for single-phase
transformers. What does the
loss in the secondary wiring
have to do with the size of
the wire in the transmission
line?   A. T. A.

For ordinary computation the effi-
ciency of the transformer and the
drop in the secondary circuit may be
neglected in figuring the size of wire
for the transmission line with a
given allowable drop. The power-
factor is more important, but, with a
transformer of ordinary regulation
on a non-inductive lamp load, it may
be assumed to be 100 percent. The
formula would then be (D x W) ÷
(P x E²) x 2 000, which gives 44 300
as the required circular mils. No. 3
wire gives 52 624 circular mils. with a
voltage drop equal to 9 percent of
the voltage received at transformer.
No. 4 wire gives 41 734 circular mils.
and a corresponding drop of 11 per-
cent.   H. M. S.

276—Disintegration and Operat-
ing Temperature of Trans-
former Oil—To what percent
is the insulating quality of
transformer oil reduced after
a short-circuit in the trans-
former? Can the oil still be
used in the transformer? At
what temperature should wa-
ter-cooled transformers be op-
erated?   W. R.

An ordinary short-circuit should
not affect the oil unless the trans-
former remains connected to the line
until the fibrous insulating material
is burned away from a large area.
Carbonized insulating material, if
present in appreciable quantities, will
accumulate in the windings and on

the terminal boards of the transformer. Whenever carbonized material lies beteween points of considerable potential difference breakdown from surface leakage will result. Another cause of trouble lies in the accumulation of solid particles in the oil on the surface of the cooling coils of water-cooled transformers, which increases the difference in temperature between the water and the oil. Filtering the oil through two thickness of unsized cambric, after a short-circuit has occurred, should remove any danger of trouble with the transformer, from this source. However, the original trouble is often caused by water in the oil. To eliminate water requires further treatment which can be most easily and effectively carried out by means of a dehydrator which filters and dries the oil simultaneously without heat. If there is no dehydrator available, the most convenient method of drying may be used, the oil being filtered also to remove all solid particles.

The question concerning the proper temperature for operating water-cooled transformers does not permit of a direct answer since different transformers vary in this respect. When in service the temperature of the transformer is generally determined by the thermometer on the tank. This measures the temperature of the oil. Some oils will not stand 70 degrees C without disintegration, which may be manifested by a deposit gathering on the cooling coils in such quantities as to retard the absorption of the heat, the water passing through the coils in extreme cases, with little or no rise of temperature, although the oil may be hot. Oil for use in water-cooled transformers should be specially prepared to prevent the formation of this deposit at any temperature which is safe for fibrous insulation and should not throw down desposits at 70 degrees C. While the transformer windings are always hotter than the oil, the difference of temperature depends on the design. Liberal ventilating ducts between the windings may keep the temperature of the copper close to that of the oil at normal load, but this difference varies approximately as the square

of the change of current in the windings. A transformer designed to run at rated load with the oil at a temperature of 40 degrees C above the entering water is generally also designed to run at 125 percent of rated load with an oil temperature of 55 degrees C above the entering water. The standard temperature of the entering water, when making guarantees, is taken at 15 degrees C. This would result in oil at 70 degrees C. When designed for this oil temperature at guaranteed load, the windings will be at a safe temperature. It is possible to run this same transformer at a higher overload and still keep the oil at 70 degrees C by the use of colder water or by increasing the surface of the cooling coils—but not by using more water at 15 degrees C and the same coils. The practice of forcing a transformer in this way is not advisable, because, although the oil is maintained at normal temperature, the coils may have an unsafe temperature due to the fact that the difference between copper temperature and oil temperature changes approximately as the square of the change of load. The exact coil temperature depends on the current density in the copper, the insulation between the copper and the oil, and the arrangement of ventilating ducts. In general, therefore, it is unsafe to try to rate up transformers without first consulting the manufacturers. J. E. M.

277—Oil Switches on Direct Current — Are oil switches practicable for interrupting heavy direct-current circuits of 5 000 to 10 000 amperes capacity at 120 to 600 volts? I have been successful with such switches for alternating-current circuits, but with direct-current the oil seems to be liable not to extinguish the arc, the result being that the oil takes fire. Do you know of some applications where such switches are operating satisfactorily? F. D.

There is a general prejudice against oil breakers for direct-current service for the reasons mentioned: We know of no installations except for comparatively low cur-

rents. In the switches of larger capacity, heavy explosions will likely result, due to the formation of gas. They are very generally used on direct current arc circuits but a much larger insulation and breaking factor must be allowed than for the corresponding alternating-current voltage. See also No. 94 in the JOURNAL for June, 1908. F. W. H.

278—OLD METHOD OF CONNECTING SWITCHBOARD AMMETER AND INTEGRATING WATTMETER— How can the current and power in the three lines of a three-phase, three-wire generator circuit be measured with the arrangement of circuits show in Fig. 278 (a), using two series transformers. A. H. M.

When the plugs are in receptacles 3 and 4 the ammeter indicates the
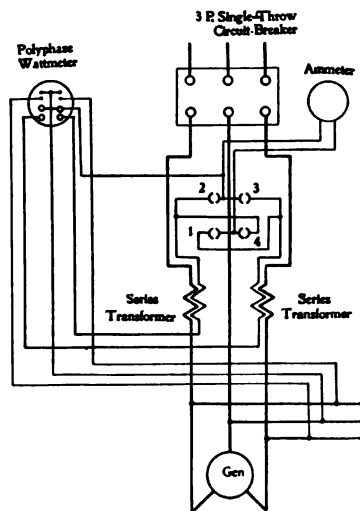
FIG. 278 (a)

current in the left hand line. When in receptacles 1 and 4 it indicates the current in the middle line, and when plugs are in receptacles 1 and 2 the ammeter indicates the current in the right hand line; while, with plugs in receptacles 2 and 3 it indicates zero. This represents one of the old methods of switchboard connections and has the advantage of requiring only a simple form of plug and the disadvantage of requiring the handling of a number of plugs

to obtain readings on the respective lines of the circuits. A polyphase indicating wattmeter may be connected to the same two series transformers through these receptacles, using the necessary shunt transformers for the voltage connections, so that the total power on the three-phase circuit may be obtained with any of the combinations referred to above. H. W. B.

279—SYNCHRONIZING BELT-CONNECTED ALTERNATORS—In the second "Experience on the Road" article in the March, 1909, issue, it is stated that, "These generators were belt-connected to the same countershaft." Is it possible to operate two alternators in parallel when so connected; if so, by what means are they synchronized if they have the wrong phase relations at starting? How are they kept in place, taking into account slipping of belts, etc.? J. G. B.

It will be noted that, in attempting to remedy the trouble, the coupling was bolted together in order to eliminate the friction clutch, as it was thought that the latter was not effective in holding the machines together. This, however, was not the difficulty. After the permanent coupling had been made, it was found in this particular case that by being brought up to speed, and without being electrically inter-connected, the two machines would come into a condition of synchronism at intervals of about 40 seconds, the difference in speed probably being due to slight differences in the effective sizes of the pulleys. It was, therefore, possible to synchronize without difficulty. If this time interval between two machines to be paralleled is too great it can be reducted by temporarily increasing the belt slip on one of the machines. This is accomplished by slightly reducing the belt tension, preferably on the loaded machine; re-adjustment being made, if necessary, after the process of synchronizing has been completed, in order to obtain proper division of load. Two alternators which have been synchronized and are thus electrically inter-connected will continue to operate satisfactorily in par-

allel if the tension of the two belts is properly adjusted, as any tendency in one machine to pull out of step causes cross-currents to flow between the two machines, which have the effect of strengthening the tendency to operate in parallel. In similar cases it has sometimes been found necessary to reduce the size of one of the pulleys very slightly by grinding to obtain satisfactory operation in parallel without excessive belt slip.   C. H. S.

280—EFFECT OF AGEING OF IRON ON RATIO OF INSTRUMENT TRANS-FORMERS—Is any change apt to take place in the iron of transformers that would change the ratio? The transformers under consideration are used in connection with portable instruments used in testing work?   W. S.

The ratio of transformation of instrument transformers is affected by the iron loss. That of the shunt or voltage transformer is slightly affected by changes in the iron loss and in the reactice e.m.f. due to the magnetizing current. In the series or current transformer the iron loss is the chief cause of the error in the ratio of transformation and of the phase displacement between the primary and secondary currents. A change in the iron loss of the instrument transformer will therefore affect its accuracy to a greater or less degree. Further information regarding this may be obtained by reference to the article on "Operation of Series Transformers" by Mr. E. L. Wilder, in the JOURNAL for September, 1904, p. 541. See also article on "Measurements Involving Use of Series Transformers" by Mr. H. B. Taylor, April, 1907, p. 234. The bearing which the regulation characteristics of instrument transformers have upon their use in the case of grouping of instruments is discussed in the October, 1908, installment of the series on "Meter and Relay Connections" by Mr. H. W. Brown, pp. 597-8. The iron or core loss of transformer sheet steel increases slightly with use. This is called "ageing." The percentage increase varies with the grade of iron and the temperature and length of oper-

ation. In power transformers the iron loss is usually guaranteed not to increase more than five percent after one year's operation. As voltage and current transformers for portable testing purposes are usually designed to operate with a very low temperature rise and are also used only intermittently, the ageing should be practically negligible. The alloy steels used in recent designs of transformers are practically non-ageing. See also No. 286 in this issue and No. 147 in the September, 1908, issue.   A. D. F.

281—DRILLING SLATE AND MARBLE—What is the best method of drilling various grades of slate and marble? At what speed should the drill be run and what feed is allowable?
                    N. P. F. D.

Use ordinary twist drills for holes 1½ inch or less in diameter, giving the lip plenty of clearance; above this size, wing cutters will give better results. Keep tool thoroughly wet with water while cutting, and keep clean to avoid jamming. A speed of 400 r.p.m. for ¾ inch or less and 200 r.p.m. above ¾ inch will be found satisfactory. Feed by hand and be careful when nearly through, as the material is apt to break off in large pieces; for this reason a machine feed is not desirable. This applies to both slate and marble.   O. L.

282—METHOD OF LOADING WATT-METERS FOR POWER-FACTOR TEST—Please suggest a simple method of obtaining loads at power-factors varying from 100 to 50 percent for testing single and polyphase watt-meters, to be used on a three-phase star-connected circuit.
                    M. C. H.

A good method is described by Mr. H. B. Taylor, in the first article of a series on "The Standardizing Laboratory" in the JOURNAL for November, 1906, p. 624.   H. E. B.

NOTE—In the article on "Illumination Cost Factors" in the June issue on page 341, in the comparison of five sources of light, the figures for the wattage required, in each case should be divided by ten to give the correct figures.

An Advance in Metal Working

Every advance in the art of working metals has meant ultimately an advance in civilization. True, in past ages each advance was used in the making of more destructive engines of war with which to enslave other nations, and hence, in many cases, caused a temporary backward step. To-day each new method marks an important step in the arts of peace, and becomes an immediate factor in the civilization of the world.

Just such a factor is the oxy-acetylene blow-pipe, giving us a new tool capable of producing results which were impossible prior to the development of the device. The use of this tool makes it possible, for example, to produce a finished vessel of homogeneous metal—a single kind of metal in a single piece—without brazing, or rivets or solder; of a shape previously possible only with cast metal, and of a quality and thinness of wall possible only with metals that have been worked into sheet form.

Mr. Auel's article on "Autogenous Welding" in this issue of the JOURNAL gives a brief and specific outline of the art as it stands to-day, with sufficient information to guide materially those who are contemplating the use of this process. The article is a distinct contribution to the literature on the subject, and will undoubtedly be welcomed, not only by those engaged in fields of metal-working where the process will be applicable, but by all who are interested in new and refined applications of scientific knowledge.

To those familiar with the welding of iron and other metals by the ordinary methods, autogenous welding is striking from its absence of the spectacular. The blow pipe, almost as easily manipulated as a pencil, with a working flame scarcely half an inch long, with a pencil-like point, produces a heat so intense that all ordinary metals melt before it in a few seconds. With this pencil of flame the skilled welder advances from point to point, with a strip usually of the same metal as solder, leaving little pools of molten metal which solidify quickly and produce a solid joint; or, supplied with an extra stream of oxygen, he wields the torch as a knife, and cuts the hardest metal walls almost without labor.

We watch the process with fascination, through colored glasses, and wonder what ultimate advantages will accrue from the use of this method, and whether it may not mark a new era in the metal-working industry, such as some of the early discoveries mentioned in the article, "How the Iron Master Has Promoted Peace," which is printed in this issue.

C. E. Skinner

The A. I. E. E. Convention

"How to Progress" was the question which was uppermost at the convention of the American Institute of Electrical Engineers at Frontenac. The dinner of delegates from the Branches of the Institute—from Seattle and Los Angeles and Mexico City to Boston—was of such rousing interest that it did not adjourn for the evening technical meeting. Representatives from about half of the fifty local centers were present. Three years ago, on a similar occasion, the work of the branches was described to prove that their existence was justified; this year the discussion was constructive and pointed out ways of larger growth. It was agreed that the local strength must come mainly from local endeavor, but there is need of the general assistance which an officer, such as a general branch secretary could give, and of the encouragement which a larger publication of branch papers in the proceedings would afford.

The past-presidents had opportunity to draw from their experience and wisdom in advising the incoming president as to the many important problems he should solve, when they breakfasted together from eight o'clock until after ten. The great problem is an Institute enlargement which will do for the various diversified divisions of electrical engineering what the local branches are doing for the geographical problem.

Electrical engineers are divided in interest into many groups, each interested in its own particular subject. There is a natural tendency to form small, independent societies. Shall the Institute resist this tendency, or quietly permit active independent development to draw from its own proper strength, or shall it foster this development within itself? If so, how? Shall it be by technical sections, or by affiliated societies? These are some of the questions which were discussed.

President-elect Stillwell, when introduced to the Institute,

spoke of the importance of development, both geographical and technical, and of the larger activity and influence which engineers and engineering societies should exert in relation to public affairs. The conditions were never so favorable for scientific and professional men and societies to exert an influence upon the world of industry. Many of the most important national problems are primarily engineering problems. The improvement of waterways, for example, is not merely political or commercial, but is engineering. The fundamental factor—an engineering demonstration that transportation by water is cheaper than transportation by rail in any given case—is often overlooked by enthusiastic promoters of waterways.

The technical meetings were good; the social and recreation features excellent, being favored by ideal surroundings, charming weather and the guidance of a committee whose happy foresight and tact made recreation an informal pleasure and not a formal task.

On the other hand, excellent as was the convention in many ways, it falls far short of what a convention of American electrical engineers should be. American manufactures are doubling every ten years. The electrical industry doubles every five years. The Institute membership has been doubled every three years, and yet this annual convention at which about 200 members were present, was smaller in attendance and not notably different in its technical papers from the conventions of ten years ago. Some important branches, such as lighting and railway, were not represented in the list of papers. One reason for this is undoubtably the large number of conventions which are held each summer. Conventions of Electro-chemists, of Illuminating Engineers, of the National Electric Light Association, and the American Street and Interurban Railway Association, all make demands upon the electrical engineer, and as they deal with concrete branches of the subject they draw a large attendance from those who are specially interested in their respective subjects. This condition emphasizes the importance of a new attitude toward different branches of electrical engineering, and of means of their concrete development. An arrangement by which the Institute would be the central body with various affiliated societies in various branches, somewhat similar to the American Association for the Advancement of Science, is a general plan strongly advocated by Dr. Steinmetz. It would go far in solving

the convention problem, as these various societies could hold simultaneous meetings as part of a general convention which would be a large general gathering of electrical engineers.

How to keep pace with the general development in the electrical industry and to take a position of leadership in those general interests in which electrical engineering enters as an important element are some of the large questions by which the Institute is confronted and in which all electrical men are interested.

CHAS. F. SCOTT

**The
Causes
of
Failures**

A structure fails—was it due to defective design, or defective material, or defective workmanship? Every engineer, every manufacturer of materials, and everyone responsible for workmanship has faced these questions many times. How many of us are able to lay aside our personal point of view and answer them strictly in accordance with the facts? And even if we have the judicial mind to so answer them, can we always locate or define the line between these three main causes of failure? Are we sure the material was at fault, or was it improperly used? Did the workmen understand and carry out the ideas of the designing engineer, or were these ideas impracticable with the tools available?

A masterly analysis of the above questions is presented in the recent presidential address of Dr. Charles B. Dudley before the American Society for Testing Materials, reprinted in another part of the JOURNAL. Anyone, whether he be the designing engineer, the manufacturer of raw material, the manufacturer of the finished product, the workman at the bench or the man who is interested in modern industrial methods, cannot but have a broader view of the problem as a whole and his own personal relation to it by the reading of this address.

Most JOURNAL articles are on specific subjects, and hence appeal only to those interested directly in these subjects, but this paper on "Engineering Responsibility" will appeal to all readers, from the general manager, charged with the duty of making the present business pay and building a reputation for his company for the future, to the humblest workman who is really desirous of rising to the best that is possible in his vocation.

C. E. SKINNER

AUTOGENOUS WELDING

WITH SPECIAL REFERENCE TO THE USE OF THE OXY-ACETYLENE PROCESS

C. B. AUEL

SINCE the advent of high speed steels one of the most impor-
tant advances, to the engineering industries at large, is the de-
velopment of autogenous welding. By this is meant the fusing
together without pressure of two metals, simply by allowing them to
melt, then to mix and unite as they cool. While this can be accom-
plished in several ways, by electricity, by oxy-hydrogen, by oxy-gas,
or by oxy-acetylene, the last mentioned is beginning to be quite gen-
erally understood when reference is made to this kind of welding.

Eliminating consideration of electrical methods, the apparatus,
briefly outlined, includes a suitable blowpipe with facilities for ob-
taining a supply of oxygen and either hydrogen, coal gas, or acetyl-
ene, the blowpipe differing somewhat with each of the three com-
bustible gases. Such outfits for use with oxygen and hydrogen have
been familiar for many years in laboratories where, however, almost
their sole function has been the reduction of elements rather than
the welding of metals. The quite recent development of commer-
cial methods for making oxygen, has now broadened the field of use-
fulness of this apparatus by placing within reach of practically all
engineering industries, a simple and very inexpensive means of join-
ing together similar metals, largely effected, heretofore, by the more
complicated and less satisfactory processes of riveting or brazing.
In addition, new methods of manufacture have been introduced
along many lines and the repairing of broken or defective parts
has become an industry in itself.

Considering only the oxy-acetylene process and describing the
apparatus more in detail, it consists, in its most common form, as
shown in Figs. 1 and 2, of a blowpipe, a tank containing oxygen un-
der pressure, an acetylene generator and its storage reservoir, to-
gether with suitable valves and hose. A more complete outfit com-
prises a generator and a tank for the manufacture and the subse-
quent storage of the oxygen. This equipment may be still further
amplified by the addition of a compressor for reaching higher pres-
sures, where necessary, than can be obtained from the oxygen gen-
erator direct.

BLOWPIPE OR TORCH

The French must be given credit for the development of the

first commercially successful oxy-acetylene blowpipe or torch. In 1901, Fouché and Picard exhibited before various French Societies, a torch in which both gases were supplied under high pressure, the acetylene being diluted with gasoline or ether to aid in preventing "back-fire." In 1902, Fouché succeeded in developing a high pressure torch in which the oxygen could be used with the acetylene undiluted. Practical use of this type of torch, however, soon indicated an inherent defect, in that the pressure of the issuing gases tended to blow away the metal from the weld as fast as melted. This difficulty accordingly led to the further development, also by Fouché (1903), of the present low pressure torch now so largely em-
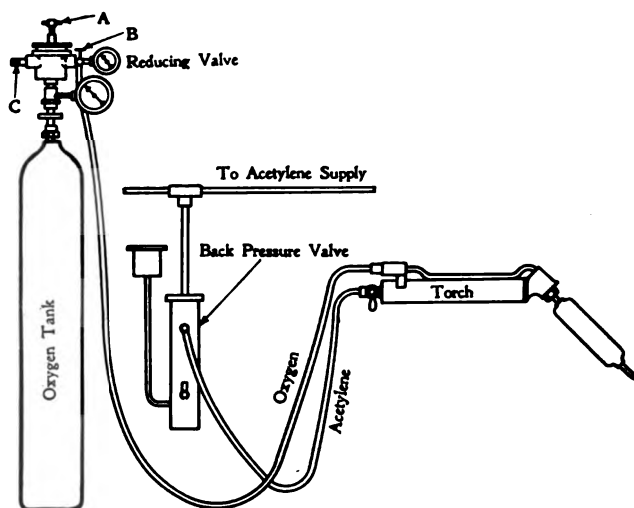
FIG. I—OXY-ACETYLENE WELDING OUTFIT

ployed. In this latter type, the oxygen is used under a pressure ranging from nine to thirty pounds depending upon the nature of the work, while the acetylene is supplied under a still lower pressure, varying from a few ounces to several pounds according to the style of torch of which there are a number now being exploited. Figs. 3 and 4 show an exterior view and a longitudinal section respectively of one of these torches. The oxygen flows through the upper pipe directly into the torch to the small mixing chamber, the acetylene being conveyed separately through the lower pipe to the same place where the gases then mix and pass out at the nozzle or tip. As the velocity of the explosion wave is extremely high, the tendency to "back-fire" must be guarded against. By making the acetylene

pipe as small in section and as long as possible, and further by giving to the oxygen a velocity of not less than 500 ft. per second, this is effectually accomplished. The capacity of a torch is determined by the orifice in the nozzle. In some makes the nozzle is accordingly removable and a number of different sizes are provided, these being readily interchangeable to suit the work; in others, the nozzle is fixed, a separate torch being required for each class of work. The
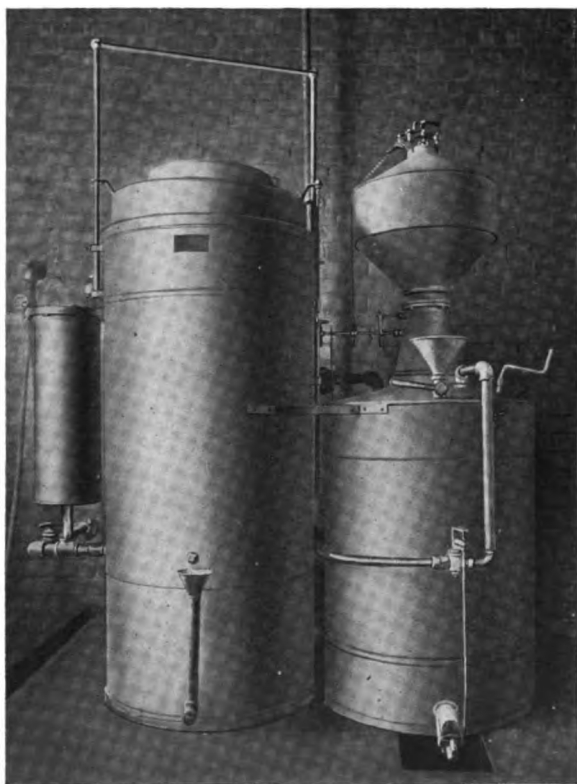
FIG. 2—ACETYLENE GENERATOR
(Monarch Acetylene Co.)

former is the more flexible; but, where large quantities of any one kind of material are the rule, either torch may be used with equal advantage.

TEMPERATURE OF FLAME

From the equation for the complete combustion of acetylene
$$C_2H_2 + 2.5\ O_2 = 2\ CO_2 + H_2O,$$
it will be observed that two and one-half volumes of
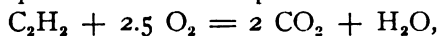
oxygen, *O*, are theoretically required to one volume of acety-lene, C_2H_2, producing two volumes of carbon dioxide, CO_2, and one volume of water vapor, H_2O. The amount of oxygen actually consumed, however, is considerably less, it being variously stated as from one and one-tenth to one and eight-tenths volumes, to one of acetylene. In explanation of this fact, it may be stated that the temperature of combustion is greatly in excess of that at which steam dissociates. As a result the hydrogen in the acetylene does not unite with the oxygen from the torch to form water vapor, as indicated in the preceding equation, but passes rather to the outer edge of the welding flame, where it comes into contact with the cooler surrounding air, extracts the oxygen from it, burning at a reduced temperature, and forming water vapor in so doing. It is further probable that the combustion of the carbon is not al-ways complete, so that the resulting mixture contains at times, in ad-

FIG. 3—WELDING TORCH—EXTERIOR VIEW
(Fouché.)

dition to the hydrogen, carbon monoxide and carbon dioxide gases. The welding flame proper is surrounded by an irregular semi-lumin-ous, pink flame of lower temperature, which not only serves to pro-tect it from loss of heat, but also tends to prevent oxidation of the metal when being melted, by keeping it to some extent from contact with the air.

CALCIUM CARBIDE AND ACETYLENE

Acetylene when burned in air gives rise to a relatively cool temperature of 1800 degrees F. as compared with 2500 degrees F. for coal gas and 3500 degrees F. for hydrogen. If these were the highest temperatures attainable, neither acetylene nor coal gas would be especially suitable for welding; burned in oxygen, however, in-stead of in air, quite different results are obtained, particularly in the case of acetylene which then gives a temperature of 6300 degrees F., or but a few hundred degrees less than that of the carbon elec-tric arc, while under similar conditions coal gas gives 3000 degrees F. and hydrogen 4800 degrees F. It is, of course, understood that

the several temperatures mentioned are approximations only, as no exact determinations have yet been made. These increased temperatures will be the more readily appreciated when it is remembered that air is composed of nitrogen and oxygen in the proportion by volume of seventy-nine parts of the former to twenty-one parts of the latter. Since nitrogen is an inert gas, and forms such a great proportion of the air, the heat of combustion is largely expended uselessly upon it, thus materially lowering the temperature of the flame; whereas, when oxygen is substituted for air, this waste of heat is entirely avoided.

Although acetylene was first produced in 1836 by Davy (Edmund) from a by-product obtained in the production of metallic potassium, and its further production direct from calcium carbide was announced by Woehler in 1862, it is exceedingly interesting to note that, outside of laboratory work, no use was made of this knowledge until 1892. At this time Thomas Willson, an electrical
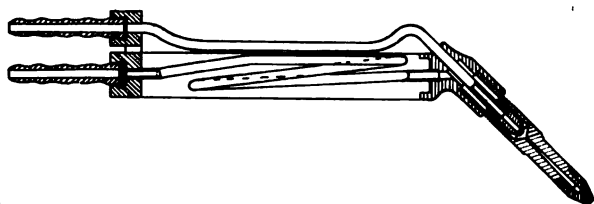
FIG. 4—WELDING TORCH—INTERIOR VIEW
(Fouché.)

engineer, while endeavoring to make metallic calcium from lime and coal tar, through the medium of the electric furnace, obtained a dark colored slag which he placed in water in order to cool quickly, when it at once commenced giving off gas. It was thought at first the slag was the metallic calcium sought and the gas hydrogen. Upon igniting the gas, however, it burned with an intensely yellow flame accompanied by a large amount of soot. The experiment was repeated several times with like results. Analysis then showed the slag to be calcium carbide and the gas acetylene. This general method, first outlined by Willson, is followed to-day in the commercial production of calcium carbide, CaC_2; lime, CaO, and coke, C, being intimately mixed together and then fused in the electric furnace, the equation being,

$$CaO + 3 C = CaC_2 + CO.$$
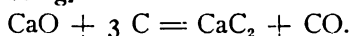
The resultant calcium carbide is a slag of a dark blue-gray color. When kept dry it undergoes no change whatever; and, in this condition, is absolutely safe to handle. Exposed to air, it absorbs mois-

ture, gradually slaking and giving off acetylene, which last fact is readily evidenced by a peculiar onion-like odor. The gas is not actively poisonous when inhaled in small quantities. It is only when calcium carbide is wet that there is any possibility of its becoming dangerous; and then, only when the resulting gas is allowed to mix with air in a confined space. Mixtures of acetylene and
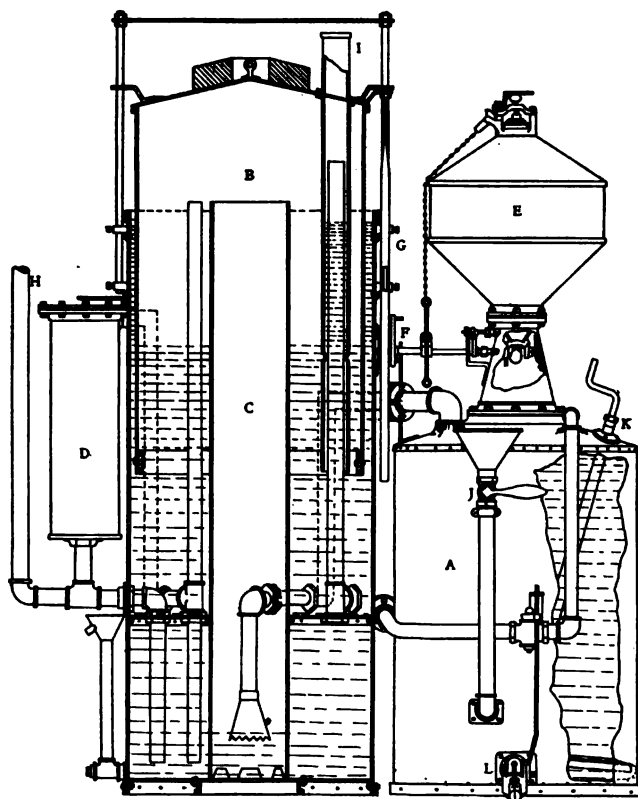
FIG. 5—SECTIONAL VIEW OF MONARCH ACETYLENE GENERATOR
A—Generator tank. B and C—Gas holder. D—Filter. E—Carbide hopper. F and G—Feeding mechanism. H—Acetylene service supply pipe. I—Safety blow-off. J—Generator water filling valve. K—Residue agitating paddle. L—Residue and waste water discharge valve.

air, between the limits by volume of one of the former and one and one-quarter to twenty of the latter, will explode with more or less violence when ignited; in which respect, however, it does not differ appreciably from common illuminating or any other combustible gas.

When, therefore, calcium carbide is brought into contact with water, acetylene is evolved, as indicated by the equation,

$$CaC_2 + \cdot 2\ H_2O = C_2H_2 + Ca\ (OH)_2$$
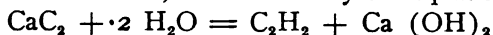
the by-product being slaked lime, $Ca\ (OH)_2$. As there are always certain impurities present, either in the carbide or in the resulting gas, such as carbon, sand, hydrogen sulphide, ammonia, etc., the yield of acetylene at atmospheric pressure from a pound of commercially pure lump calcium carbide ("quarter" size) may be taken as from four to four and one-half cu. ft. instead of five and one-half cu. ft. as would be the case were the carbide absolutely pure.

In the commercial manufacture of acetylene either of two methods may be followed; calcium carbide may be dropped into water, or water may be dropped upon carbide. Generators employing the former method are designated as "carbide-feed," those making use of the latter are known as "water-feed." In either of these types the gas may be generated at pressures ranging from six ounces to fifteen lbs. per sq. in., depending upon the design.

While each has its advantages, the carbide-feed generator is the more widely used, especially in connection with oxy-acetylene welding plants. Figs. 2 and 5 show one form of such type. It consists of two principal parts, the generating tank, in which the acetylene is produced, and the reservoir or holder where it is stored. The generating tank is provided at its top with a hopper into which the charge of lump carbide is placed and from which it is fed, a little at a time, into the water with which the lower part of the tank is filled. The storage reservoir or gas holder is of the usual bell pattern, water-sealed, its top raising or lowering with increase or decrease of gas pressure, and operating in so doing, a simple mechanism of levers and cogs by means of which the feeding of the carbide from the hopper on the generating tank is controlled. Although the water in which the acetylene is formed and through which it bubbles, acts as a cleanser, an additional filter is provided in the shape of a small tank filled with felt, through which the gas passes after leaving the holder on its way to the service pipes.

In the water-feed generator the carbide is placed in trays arranged either one above the other, or side by side, in such manner that water floods them one at a time, the speed of flow being governed by the pressure of the gas. The acetylene then passes through a filter into the gas holder, which must be of larger capacity than for the corresponding size of carbide-feed generator, as the degree of regulation is never so close in generators of the water-feed type,

and the holders must, therefore, be of sufficient size to handle the "after-generation" of gas; that is, the gas which continues to be produced for some time after the supply of water has been shut off by the rise in pressure.

The capacity of an acetylene generator depends upon its ability to keep down the heat which is evolved in the formation of the gas. This plainly indicates that an excess of water should at all times be present in the generating tank, so that the heat may be dissipated as fast as created. Where such is not the case overheating takes place, the result being not only a reduction in the amount of acetylene, otherwise usefully available, but the production of certain tar products which tend to clog the piping and thus prevent a proper working of the apparatus, particularly the torch. As to whether or not the generator has been overworked is easily determined when cleaning it, which must be done upon the exhaustion of each charge of

FIG. 6—DISSOLVED ACETYLENE STORAGE TANK

carbide. If the residuum which, as indicated by the equation already given, should be slaked lime, is of a yellowish color instead of white, it shows excessive heating has occurred and the necessary steps must be taken to prevent its recurrence.

DISSOLVED ACETYLENE

It is somtimes necessary to reverse the customary procedure and to transport the welding plant to the work instead of bringing the work to it. In all such cases, dissolved acetylene is used in place of the acetylene generator. It would, on first thought, appear as if compressed acetylene were the most natural substitute, but experience has proved that when compressed to more than two atmospheres (30 lbs.) acetylene is liable to explode simply by concussion, and for this reason it cannot be used in commercial service. To overcome this drawback and make it safe to handle, advantage has been taken of its solubility in acetone, C_3H_6O, one of the constituents of wood alcohol, which has the very extraordinary property of absorbing, at normal temperature, approximately twenty-five times its own volume for every atmosphere of compression. It is accordingly forced into this liquid at ten to twelve atmospheres and in

this state is called dissolved acetylene. Even in this condition, the further precaution must be taken to prevent the accumulation of any "free" compressed gas, so called, into pockets. The tank in which the dissolved acetylene is stored, is therefore packed, as shown in Fig. 6, with a porous material like charcoal cement or with discs made from a paste of asbestos fiber and sodium silicate, $Na_2Si_4O_9$, carefully prepared, so that even when thoroughly saturated with the liquid, no shrinkage of the packing can occur. The necessity of this is the more obvious when it is considered that the volume of the acetone increases with the absorption of acetylene, at twelve atmospheres being about one and one-half times its original volume. At this latter pressure it has been estimated (Kuchel) that the solution will occupy 64.3 percent of the interior of the tank, the packing 20 percent and the free compressed gas 15.7 percent. When, therefore, acetylene is subsequently withdrawn from the tank, and the pressure correspondingly reduced, the acetone shrinks in volume with the result that a constantly enlarging space would be left for the accumulation of free compressed gas, were it not for the packing which effectually prevents it. Manufactured and stored under such conditions, it is but natural that the cost of dissolved acetylene should be considerably in excess of the cost of acetylene, made and used direct from a generator. In partial compensation for this increased cost must be mentioned, however, not only its portability, but its low freezing point as well (It can be used at temperatures as low as —49 degrees F.) which permit of its use under conditions quite beyond the range of the acetylene generator.

To anyone contemplating the purchasing or handling of an acetylene plant, it is recommended that the rules of the National Board of Fire Underwriters be studied. These have been compiled with great care after years of experience and accordingly contain information which will prove of much value not only in the purchase but also in the installation and operation of the plant as well.

OXYGEN

Oxygen may be produced in several ways, either from liquid air, by chemical agencies, or from the electrolysis of water; although this last method is but little used as yet commercially. Oxygen obtained in any of these ways is generally of a high degree of purity, varying from 95 percent to chemically pure. A plant for its production from liquid air involves heavy initial expense, though the subsequent manufacture of the gas can be carried on at a very low

figure. Such a plant, therefore, on account of its cost cannot be seriously considered by the average consumer and he has left the alternative of purchasing the compressed oxygen in portable tanks or making it himself by chemical means.

The apparatus for the generation of oxygen by chemical reaction consists of three parts, the generating tank, the scrubber or washing tank, and the storage reservoir, with sometimes the addition of a compressor.

In one method (dry) a mixture of chlorate of potash, $KClO_3$, and manganese dioxide, MnO_2, is placed in the generating tank, heat being then applied externally. In the ensuing reaction, shown by the equation,

$$8\ KClO_3 + MnO_2 = 8\ KCl + MnO_2 + 8\ O_2$$
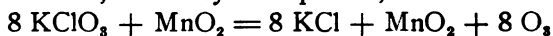
oxygen is produced, passing as fast as formed into the scrubber. This latter is a tank containing some substance such as pumice stone or pebbles, impervious to the action of the chemicals used, and which has been filled with an alkaline solution, usually caustic soda, $NaOH$. The oxygen in bubbling through is washed of any impurities and is then drawn into a compressor and pumped into tanks at any desired pressures. A slight modification of this process, which eliminates the compressor, consists in first adding to the mixture of chlorate of potash and manganese dioxide, a certain amount of carbon, after which magnesium powder or a similar ingredient is introduced and ignited. The combustion is continued by means of the oxygen which is constantly being liberated until the reaction is complete. The resulting gases, under a pressure of from sixty on one hundred and fifty pounds go through a scrubber as before where the carbon dioxide (formed from the combustion of the carbon) and any other impurities are absorbed, the oxygen passing into the storage reservoir.
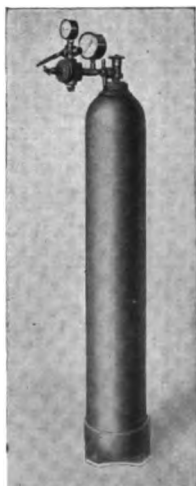
FIG. 7—OXYGEN STORAGE TANK, SHOWING PRESSURE REDUCING VALVE (Linde Air Products Co.)

In another method (wet) a solution of iron sulphate, Fe_2SO_4, is allowed to flow into the generating tank where it combines in a complicated reaction with a solution of copper sulphate, $CuSO_4$, and calcium hypochlorite, CaO_2Cl_2, to form oxygen. The gas is washed as in the two preceding processes and then compressed.

It should at all times be borne in mind that oil forms an ex-

plosive compound with oxygen, so that it must not be employed as a lubricant either in connection with the compressor or with any of the valves. A mixture of castile soap and water should be used instead.

OXYGEN PRESSURE REDUCING VALVE

In welding (not cutting) the oxygen is used in the torch between the limits of nine and thirty pounds only; it is, therefore, necessary to reduce the pressure at which it is usually supplied and this is effected by a regulator, one form of which appears on the top of the oxygen tank in Figs. 1 and 7. Two gauges are attached to it, as shown, the larger one indicating the pressure in the oxygen tank, the smaller one, the pressure after passing through the regulator and as it is in the torch. Adjustment of pressure is obtained by means of the thumb-screw, *B*, Fig. 1, while the set screw at the top, *A*, shuts it off entirely. For the convenience of the operator, the larger gauge is calibrated to show both pressure and cubical contents; the smaller gauge to indicate the correct pressure to employ for each size of torch or nozzle. A safety-valve connecting with the low pressure side is located at the left, *C*, this being set to blow at a pressure slightly in excess of the highest normal working pressure.
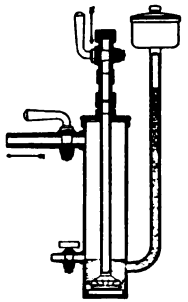
FIG. 8— ACETYLENE BACK PRESSURE VALVE (Linde Air Products Co.)

ACETYLENE PRESSURE REDUCING VALVE

Acetylene may be generated, as before stated, at pressures varying from a few ounces to as high as 15 lbs., depending upon the make of generator. Except with the lowest pressures a reducing valve similar to the oxygen pressure reducing valve is generally used which maintains the supply of acetylene constant at some pressure below the maximum.

ACETYLENE BACK PRESSURE VALVE

From what has already been said, it is perfectly obvious that it is necessary to prevent either air or oxygen from passing back through the pipes into the acetylene generator. This is accomplished by an hydraulic valve, which operates as indicated in Fig. 8, the travel of the acetylene being normally in the direction of the arrows. Should the generator be not working or the nozzle of the torch be clogged, there would be a tendency for air in the first in-

stance and oxygen in the second, to flow back into the generator. This, however, is prevented by the water in the valve, part of which, when the pressure is sufficiently high, is forced into the pipe leading to the generator, thus sealing it, while part is forced into the relief pipe to the chamber at the top where the pressure is re-leased, the water falling back into the pipe.

ADJUSTMENT OF FLAME

In lighting the torch, the acetylene is first turned on and ignited, then the oxygen, the small gauge on the oxygen tank being set to correspond with the size of torch or nozzle used. No further ad-justment of the oxygen is necessary; the acetylene may, however, require some regulation, this being easily accomplished by the valve controlling the supply. In extinguishing the torch the acetylene is turned off, then the oxygen. When the gases are properly propor-tioned, Fig. 9, a small intensely blue cone of flame is produced di-

FIG. 9—WELDING FLAME
Gases properly proportioned.

FIG. 10—WELDING FLAME
Acetylene in excess.

rectly at the tip of the torch, being always accompanied by the en-veloping, semi-luminous, pink flame, already described. An excess of acetylene, Fig 10, is indicated by the formation of two small cones (plainly visible through colored glasses) one extending be-yond the other, the light being very white; the metal is also car-bonized and a deposit of carbon settles about the weld. Too much oxygen is indicated when sparks are given off freely, showing ox-idation of the metal, and the flame takes on a violet tint which, however, is not easily distinguished; the weld has, further, a fine spongy appearance. From the preceding it is quite evident that either a neutral, an oxidizing, or a reducing flame may be obtained as desired. Except in very special cases, a flame as nearly as pos-sible neutral in character leaning, if anything, to the reducing, should be employed.

WELDING

In welding, cleanliness is of the very first importance,

and the necessity for this cannot be too strongly emphasized   It should permeate everything.   Inability to obtain the best results may oftentimes be traced to impurities either in the chemicals used, or in the gases; it may also be due to carelessness in handling or caring for the apparatus, or it may even be the result of failure to clean the metal where the weld is to be made.   There is another and almost equally important point to which attention should be called, namely, the tendency to overdo welding.   Owing to the comparative facility with which welds can be made, it not infrequently happens that repairs of this kind are effected on castings, etc., which should
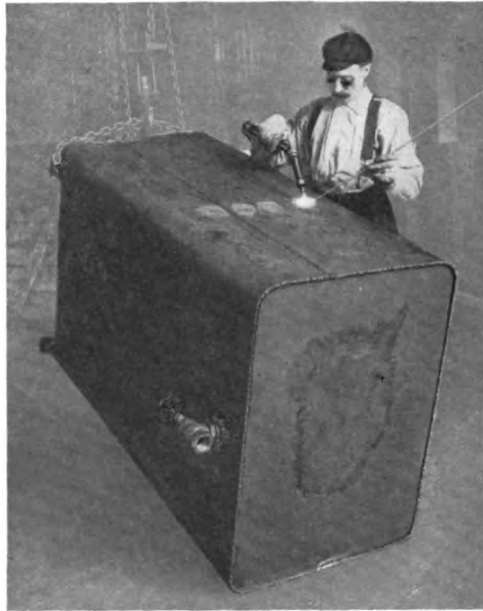
FIG. 11—WELDER AT WORK

properly be consigned to the scrap pile and which would be, were the relative costs of repairs and new materials estimated in advance.

Figure 11 shows a weld being made.   It will be noted that no protection is needed for the operator except for the eyes, the process differing markedly in this respect from arc welding where the entire body must be covered.   The workman holds the torch in one hand, the welding stick in the other, the two almost touching and practically forming an angle whose apex (including the blue cone of flame) is within 1/32 to 1/4 inch of the metal being heated.   As

the metal melts, the torch and the welding stick still forming the same angle are moved along, the operation being continued until the welding is completed. Where great strength is required the section of the metal at the weld may be enlarged. If it be desired to give the metal a closer grain, thereby toughening it, the weld may be hammered after being made and while still soft. Annealing is also very beneficial though it is not necessary in the general run of work. In the repairing of cracks, it is positively essential that the metal either be chipped, machined, or burned down to the bottom of the crack before commencing to weld. In this way only will a perfect weld be secured. When in the course of a machining operation a defect is discovered which can be remedied by welding, it is advisable to weld at once without continuing to rough finish the piece so that if warping

FIG. 12—TYPICAL WELDS SHOWING JOINTS

does occur, as is likely to be the case, no harm will be done. Hollow castings, of whatever metal, should be well packed with perfectly dry moulding sand, not only to aid against warping but, when welding holes, to serve as a background for the metal being added.

SHEET IRON AND STEEL

Sheet iron may be welded even more satisfactorily than sheet steel and should be used in preference to it whenever possible. In sheet metal work, the welds are practically all "butt" instead of "lap." When the thickness of metal is more than 3/16 inch, the abutting edges should be beveled either on one or both sides. It is sometimes even advisable to bevel sheets but 3/32 inch thick, as experience will, from time to time, demonstrate. If the shape of the

piece does not permit of this being done by machine, which is usually the cheapest method, it must be done with the aid of the torch, otherwise the weld will be imperfect in that it is confined more or less to the surface and does not extend entirely through the metal. It will very often be necessary to spread the two sheets apart at one end, holding them rather loosely in a clamp; otherwise, as the welding proceeds, the edges will tend to overlap. The sheets may also be placed with advantage, on a slight angle in such a way that the welding travels up hill, as it were, thus allowing the metal when melting to flow back against the flame, thereby making a slightly more uniform joint. The sketches given in Fig. 12, which have been compiled from various sources, illustrate some of the many ways of making joints. The welding stick is usually of small Norway or
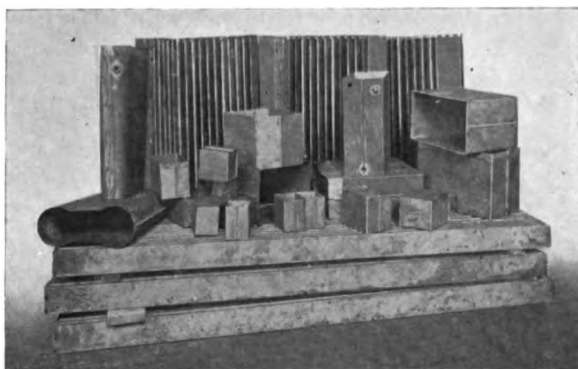
FIG. 13—WELDED SHEET METAL TANKS

Swedish iron wire; a good substitute for this is sheet iron (made from muck bar) when sheared into thin strips. Ordinarily no flux is required. Figs. 13 and 14 show a variety of welded sheet metal tanks.

WROUGHT IRON

Wrought iron is as easily welded and the results obtained as satisfactory as with sheet iron, the same method being followed in detail.

CAST IRON

In the welding of cast iron, especially when the sections are thin, it is necessary to preheat the castings slowly to a dull red, to make the welds while in this condition, then to allow equally slow cooling. Only in this way will shrinkage strains be equalized or

reduced and cracks avoided. Preheating may also be resorted to as a means of minimizing the consumption of acetylene and oxygen, thereby lessening the cost. Figures 15 and 16 show a torch and a furnace for two methods of preheating. In the one instance a generous flame, usually of coal gas and air, is directed upon the casting, heating it over a considerable area and especially in the vicinity of the weld. When the proper temperature has been reached the gas is temporarily shut off and the weld made, after which the heating flame is again directed upon the casting, being gradually reduced in amount. In the second and more complete method of preheating, a temporary furnace of fire brick is built about the casting so that it is entirely enclosed. The casting is then heated to the proper temperature, the gas shut off, one or more bricks opposite the place to be welded are removed and the weld is made. The bricks are next replaced and the casting allowed to cool off gently. A welding stick rich in ferro-silicon is recommended; copper wire may likewise be used with excellent results. A good flux consists of red oxide of iron, Fe_2O_3, and borax, $Na_2Bo_4O_7 + H_2O$, in the proportion by weight of fifteen to twenty-five parts
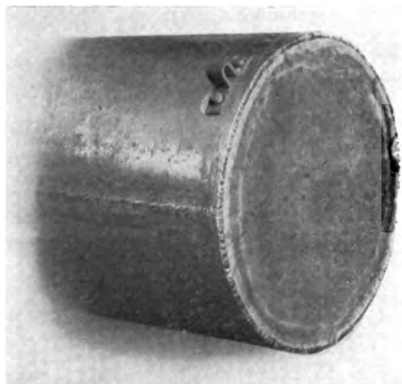
of the former to eighty-five to seventy-five parts of the latter. Borax or common salt, $NaCl$, may even be used without the addition of any other substance, though the tendency of the latter is to harden the weld.

<div align="center">MALLEABLE IRON</div>

The same procedure as with cast iron should be followed throughout, but at best the welds will not be very satisfactory.

<div align="center">CAST STEEL</div>

Cast steel is welded in practically the same manner as cast iron, except that the preheating is not absolutely necessary, though always helpful.

<div align="center">BRASS</div>

Brass is rather hard to weld owing to its low melting point.

The metal generally requires to be supported to prevent its losing shape and the torch must be applied intermittently. Soft brass wire in preference to spelter, should be employed as a welding stick. It is necessary to use a flux to prevent volatilization of the zinc, borax answering the purpose admirably.

ALUMINUM

Aluminum is without doubt the most difficult of the more common metals to weld, due to the formation of a film of oxide over
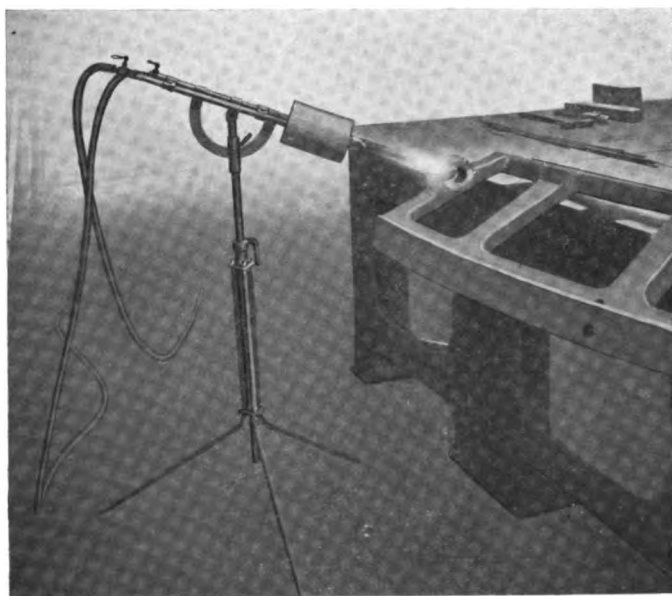
FIG. 15—PRE-HEATING TORCH

its surface which has until very recently resisted all efforts to remove it. Several authorities have lately outlined schemes of overcoming the difficulty and the problem now seems in a fair way of being solved. According to one method, the metal is quickly heated to a plastic condition in the vicinity of the proposed weld and is then puddled or worked with an aluminum rod in order to disintegrate the film of oxide. In another method which, however, is more suited for the welding of rods by the Thomson (electric) process, the metal is quickly heated to a plastic condition and the parts are then suddenly shoved together, the object being the same as in

the first method, namely, to break up the oxide. Other authorities recommend the use of fluxes, these usually being composed of potassium chloride, *KCl,* or sodium chloride, *NaCl,* sometimes both, and lithium chloride, *LiCl,* or lithium fluoride,*LiFl,* in varying pro--portions, the mixture being melted and pulverized before being used.

<div align="center">CUTTING OF METALS</div>

In addition to welding, the oxy-acetylene torch can be used for the cutting of steel or iron (not cast iron). Though not quite so economical as oxy-gas, the process can be substituted in many cases for machining, the work being done at reduced cost, in less time, with almost equal smoothness, with as little and sometimes less loss of material, and with no injury to the metal. Furthermore, irregu-

lar shapes, bevels, etc., which are entirely beyond the capabilities of standard machine tools, can readily be cut. The torch differs somewhat from the one used for welding, in that it is provided with an additional nozzle for oxygen, as shown in Fig. 17. It is, however, manipulated in much the same way, the flame being directed upon the metal at the point where the cut is to begin, and thus continued until a bright red heat is obtained. The valve on the

<div align="center">FIG. 16—PRE-HEATING FURNACE</div>

nozzle controlling the oxygen supply is then opened, allowing the jet to strike the heated spot when the metal at once commences to burn. The blast is sufficient to blow away the particles of the fused metal, leaving a clean narrow cut equal in width to the jet of oxygen, the pressure of which, as might be inferred, is considerably in excess of that used for welding, it being from one hundred and twenty-five to two hundred pounds.

<div align="center">QUALITY OF WELDS</div>

The results of tests (Reich) on 3/64 to 5/8 inch open-hearth steel sheets, show that for equal sections, the metal at the weld after annealing, has an ultimate tensile strength of 80 percent and an elastic limit of 90 to 92 percent of that of the original material; the elongation varies considerably, ranging from 16 to 53 percent of the original stock.

COSTS

It is difficult to give costs that would be of value for comparative purposes on anything other than sheet iron or steel welding, and even the data on this class of work, as stated by different writers, vary within such wide limits, that the prospective purchaser of an oxy-acetylene plant is rather bewildered as to what welding really does cost. The accompanying curves, Fig. 18, have been compiled from the mean of data published by investigators both in America and in Europe and should, therefore, represent average conditions quite closely. The prices of labor and materials differ so much that it has been deemed best to plot the curves as shown, namely in "No. of lineal feet welded per hour", "No. of cubic feet of oxygen at atmospheric pressure consumed per hour", and "No. of cubic feet of acetylene at atmospheric pressure consumed per hour", so that no matter what the range of prices may be, the total costs can still be figured with but little difficulty. Tak-
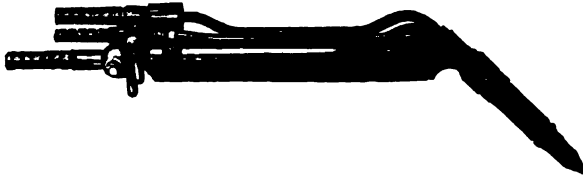
FIG. 17—CUTTING TORCH

ing for example, labor at 30 cents per hour, oxygen at three cents per cubic foot, and acetylene at 0.94 cents per cubic foot (assuming calcium carbide to cost four cents per lb. and to give 4.25 cubic feet of acetylene per lb.) the cost of welding ⅜ inch sheet metal should be as follows:—

```
Oxygen 33.25 cu. ft. per hr. at . . . . . .$0.03  =$0.997
Acetylene 23.7 cu. ft. per hr. at . . . . . . . . 0.0094 = 0.223
Labor per hr. at . . . . . . . . . . . . . . . 0.30  = 0.300
                                                         _____
Total labor and material . . . . . . . . . . .        1.520
Metal welded 7 ft.
Total labor and material cost per lineal foot . . . . = $0.217
```

Since a plant can be installed for a very small amount (from $200.00 upwards) and since the cost of operation (labor) and maintenance are almost nil, the indirect expense, including interest on investment, is practically negligible.

COMPARISON OF METHODS OF WELDING

Attempts have been made by various writers to point out the

superiority of oxy-acetylene over electric welding. Speaking broadly, the two are not comparable, each having its distinct field. The oxy-acetylene process, owing to the fineness of adjustment possible with the flame, is best adapted for welding sheet metals and for repairing small miscellaneous defects; the Thomson (electric) process requires that the metals to be welded be essentially of the same cross-section and resistance and hence is more particu-
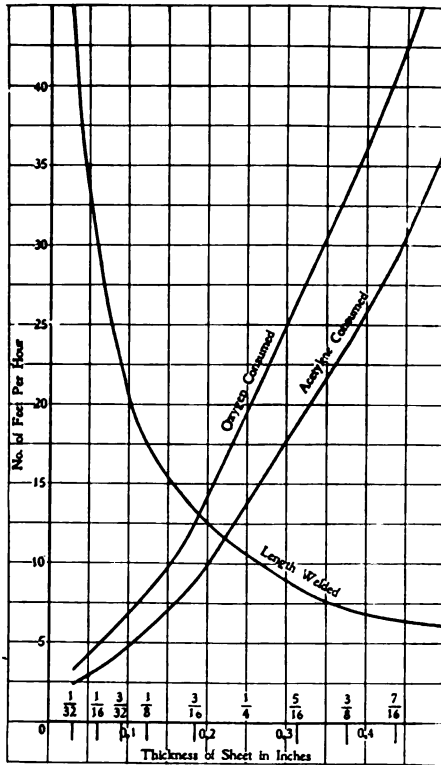
FIG. 18—RATE CURVE FOR DETERMINING WELDING COSTS

$$\text{Mean ratio, } \frac{\text{consumption of oxygen}}{\text{consumption of acetylene}} = 1.4$$

larly suited for uniting wires and rods, for making tires, putting heads on bolt and screw bodies, joining rails, etc.; the Benardos (electric) process has as its specialty the same general class of work as the oxy-acetylene process, but on a heavier and rougher scale where close regulation of the arc is not such an important consideration.

HOW THE IRONMASTER HAS PROMOTED PEACE*

THE industrial progress of the world in the past century has been most prominently in the extension of the beneficent uses of iron and steel. The ironmaster has furnished the means for plowing, planting, reaping, preparing and transporting the great commercial harvests; he has covered the world with a network of highways of steel; he has furnished the motive power, the machinery and nearly all the equipment of the countless factories which afford employment for the people, and has replaced the brick of Babylon and the marble of Greece with great structures of steel, which house under one roof the population of a small city.

A curious fact in the history of iron is that for 3000 years or more it was doubtful whether the metal was a blessing or a curse to mankind. It is only within the past century that the beneficent uses of iron and steel have become more important than the destructive use of the metal in warfare and strife. The Dark Age of Europe followed directly upon the discovery of steel, just as the earlier Dark Age of Egypt and Western Asia followed the extension of the use of bronze in that ancient world. If industry is at last triumphant in its contest with the sword, it is because the modern ironmaster has so cheapened the cost and multiplied the production of iron and steel that the sword or the metal from which to forge weapons is no longer monopolized by military caste.

For thousands of years after bronze was discovered it was a rare and costly metal, more valuable than gold. It was too valuable a metal to use in agriculture or any other base art, but a small army equipped with weapons and shields of bronze could enslave an empire of people who had no weapons but wood and stone. The valleys of the Nile and the Euphrates were populous in ancient times because their sandy, friable soil could be cultivated with wooden implements and gave quick returns to agricultural labor. The earliest historic empires were located in those valleys because they were the only places in the world of any notable magnitude where agriculture could be carried on successfully without iron; and their people fell an easy prey to the sword and became the slaves of Pharaoh and the Chaldean and Babylonian kings. The ruins of those ancient empires show that their earliest civilization was the highest and that during thousands of years there was a pro-

gressive decline, until they sunk into hopeless decay. The power of the sword in the course of ages paralyzed industry and progress and reduced the masses to a dead level of hopeless slavery under the heel of a small governing class who despised industry.

In Europe the same progressive decline is found during a period of about 2000 years—from the highest development of art and industry in Greece and Carthage to the end of the Dark Age. This decline was inaugurated by the discovery of steel. Iron was known and used at least 1000 and perhaps 1500 years before the Christian era, but until the process of carbonizing and tempering it to make steel was discovered it was inferior to bronze for tools or weapons, and the supply was so limited that, as late as the fourth century, B. C., Greek historians record the fact that iron and bronze exchanged for equal weights of gold. The Romans in their wars with Hannibal carried bronze swords and shields, and their legions were not equipped with steel swords until the middle of the second century B. C., Greek historians record the fact that iron and bronze the first of which there is any historical record in which steel replaced bronze in warfare, and it was his superiority in weapons that enabled Hannibal to carry on his long campaign against the Romans.

When the Romans obtained possession of the forges and mines in Spain, where the Carthaginians had developed the art of making steel, they lost no time in equipping their legions with the superior metal. Until that time they had made little progress in their predatory campaigns outside of Italy, but within a century after they had armed their legions with steel they had destroyed Carthage, sacked Greece and brought all Europe and Western Asia under tribute to Rome. The Romans sought only plunder, tribute and slaves. In their hands the sword once more obtained the mastery of the world and began its work of destroying, by predatory taxation and oppression, the wealth that had been created by industry. History fails to record during the next thousand years any notable invention or industrial discovery, and Rome, like Egypt and Babylonia, declined until she could no longer hold the remnants of her civilization against the hand of the barbarian invader.

Tacitus, in the first century of the Christian era, records the fact that the Germans had scarcely enough iron to tip their spears. The northen races made no progress against the Roman legions until they had obtained enough steel to place them on an equality in weapons. Once masters of Europe, the few who could afford to

clothe themselves in iron armor became barons and established a system of petty and oppressive taxation which destroyed the remnants of industry.

During the past century the iron master has convinced the world that the individual man can profit more by patient industry than by predatory warfare. The old wooden plow with a scant iron point, which was only superseded within that recent period, did not promote peace of mind in the unhappy mortal who had to use it, and the hoe and the sickle made aching backs and a desire for any change, even war, that might improve the unfortunate lot of the tiller of the soil. Modern iron and steel plows, harvesting machines and other labor saving implements have made it possible for the farmer to acquire wealth by his own labor, with all the comfort that wealth commands. Highways of steel have promoted commerce and created unlimited opportunities for profitable employment for millions of men who in former centuries chafed under the restraints and hardships of serfdom or slavery. We can scarcely realize that so short a space of time separates us from the long era of human history, extending backward into the mists of prehistoric time, when warfare and strife were the chief occupation of man and peaceful industry was shunned by all save those who were forced to labor. Yet in this short transition from predatory warfare the dominant races have realized so clearly the advantages of peace that the millions of men who carry on the world's commerce and industries command practically unanimous support from the masses when they sternly repress any political ambitions in the minds of their rulers that might lead to war again. The iron master has brought peace to a troubled world by providing the means which make labor profitable and interesting to the individual.

THE CHOICE OF A CONDENSER (Cont.)

FRANCIS HODGKINSON

TYPES

Condensers are broadly divided into two types—jet and sur-
face. In the former the cooling water is intimately mixed with the
steam, and in the latter it does not come in contact at all with the
exhaust steam, condensation being accomplished by the transmis-
sion of heat through the walls of a large number of thin, small
tubes of good conducting material, usually one of the copper alloys.
Jet condensers may be again subdivided into various types. Sur-
face condensers are of one type only. When they differ it is in
detail only and in having different types of pumps in conjunction
with them. As the two types, surface and jet, are so fundamentally
different, the first step is to choose between them—not between
various varieties of either. The parting of the ways is of the
greatest importance. The surface type will first be considered.

SURFACE CONDENSERS

Owing to their great cost as compared with jet condensers,
surface condensers should not be used except where absolutely
necessary; i. e., where lack of feed water for the boiler warrants
the extra cost. Of course there are cases, such as at sea, where
surface condensers are indispensable, otherwise the whole ship would
consist of feed water tanks without room for much else. On land,
of course, suitable feed water can always be obtained at some ex-
pense, and that cost capitalized makes it a simple arithmetical
problem to determine the extra investment permissible in order to
be able to return condensed steam as feed water to the boiler.

This is very simple as far as it goes, but unfortunately there is
another point which greatly complicates the matter, and one which
makes it impossible to give exact figures, viz., the corrosion and
deterioration of the condenser tubes themselves, the exact cause
of which is not often understood. With clean, fresh water, free
from acid, the tubes of a condenser last indefinitely, but where the
cooling water contains sulphur, as in drainage from coal mines, or
sea water contaminated by sewage, such as harbor water, the de-
terioration is exceedingly rapid, and here arises an unfortunate
anomaly inasmuch as that location where the surface condenser is
least necessary is where it will be least troublesome, and vice versa,
where it is most necessary the condenser is an endless source of

trouble. The problem would still remain simple, as with experience with the particular cooling water, the life of the tubes may be judged and the cost per annum of tube renewals estimated. This, taken into conjunction with the calculations on cost of suitable feed water, would indicate the amount which may profitably be expended on the condenser except for the fact that cost of tubes forms but a part of the maintenance. There must also be considered the labor of tearing the condenser apart and the interruption to service when tubes are being put in. For this no exact figures can be given. The user himself must make an intelligent estimate of these last items.

There is further the danger of the boilers being injured by the condenser operating for some time in a leaky condition without being discovered, thus letting a quantity of unsuitable water into the boilers. Even a temporary interruption of the condenser is of serious import as the turbine meantime may have to be operated non-condensing, at which time its steam consumption is approximately doubled, resulting, perhaps, in the boiler house being unable to meet the demand for increased steam. And here may be noted one of the disadvantages of a centralized condensing plant—the danger of a crippled power plant at times of peak load.

It is not an exaggeration to say that there are to-day a large number of surface condensers installed which may be considered as installed due to error in engineering judgment and that, in the long run, jet condensers would have been more satisfactory. For example, how many stations around New York harbor, employing surface condeners, are returning condensed steam to the boilers for even one-half the time? In fact, a few make no pretence of doing it at all. In this connection, however, it should be kept in mind that when turbines are the main units, the exhaust is uncontaminated with oil, which fact tends to make the returning of condensed steam to the boilers more attractive.

As stated, the cause of deterioration of tubes is not altogether understood. The trouble is sometimes ascribed to electrolytic action that is due to the earth currents passing by means of the salt water through the condenser. Attempts, however, made to insulate condensers and counteract these earth currents, have not been particularly effective in preventing deterioration, rather indicating that earth currents are not altogether responsible. While in harbors this trouble is most pronounced, the salt in sea water would not seem to be the sole cause, as no particular trouble is experienced in marine work. New York harbor is particularly bad,

and it is worse in the East River than in the North River. In one of the largest plants there, containing some surface and some jet condensers, it is probable that the surface condensers will be taken out and replaced with the jet type.

It is sometimes contended that a better vacuum may be obtained from a surface condenser. Possibly this is true where there is plenty of cooling water easily handled. The better vacuum is due to the fact that the air pump will have much less air to handle inasmuch as the air carried in suspension by the cooling water does not have to be extracted as in the case of jet condensers. Water in open rivers, the ocean, etc., is said to carry in suspension five percent by volume of air. It may be said that except for leakages, which should not exist, the air pump will have no work to do at all
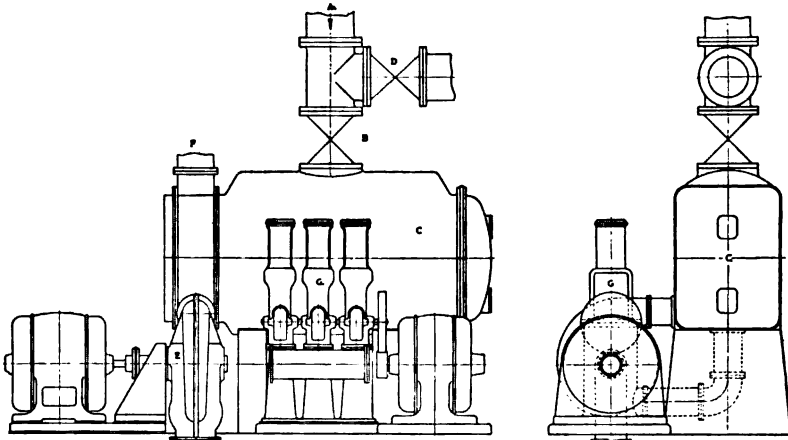
FIG. 3—CONDENSER WITH EDWARDS AIR PUMP

inasmuch as the water will have no opportunity to become aerated. The steam leaves the boiler, passes through the engine, is condensed under vacuum, is pumped from the condenser into a closed hot well, thence through the heater, the economizer and again to the boiler, throughout which cycle it is given little opportunity to absorb air. On the other hand, if the cooling water is limited, these advantages are offset by the fact that a surface condenser cannot heat the cooling water so near to the temperature of the exhaust steam as can a jet condenser. In other words, the temperature difference, the smallness of which is the measure of condenser performance, is greater in a surface condenser than in a jet condenser.

The various arrangements of surface condensers are included in the following:

Fig. 3 shows one of the most common arrangements, where *C* is the condenser with steam entering at *A*. A gate valve *B* and an automatic valve *D*, to open to atmosphere, permit the turbine to be operated non-condensing while the condenser is being repaired. The exhaust valve *D* is a simple disc valve which is kept on its seat by atmospheric pressure and will freely open when the pressure in the condenser exceeds by a small amount that of the atmosphere. *E* is the centrifugal pump, which circulates the cooling water through the condenser and discharges it at *F*. In this case a three-pass condenser is shown. Sometimes in small condensers, two passes or only one is employed. The air pump which, in this case is a wet pump and extracts both the condensed steam and the non-condensible vapors is shown at *G*. The Edwards pump is used largely for such purposes. The ordinary form of Watt pump, however, was formerly universal practice.

It is safe to say that it is only within the last few years that condensers for high vacua have been built. The advent of the turbine demanding high vacuum, has stimulated builders to

FIG. 4—VERTICAL CONDENSER WITH BOTTOM DRY AIR
PUMP CONNECTION

furnish much more elaborate apparatus and has brought about the introduction of the dry vacuum pump. Whether this elaboration is a real necessity or not, is a question. In the writer's mind a properly designed wet air pump arranged as shown at *G*, Fig. 3, is capable of giving about as good results as the more elaborate dry vacuum pumps.

Fig. 4 shows one of these condensers in conjunction with a dry vacuum pump, the letters of reference being the same as before except that *J* is the hot well pump which extracts only the condensed steam. If a duplex pump is used for this purpose, it is

usual to employ a float in the base of the condenser which will control the speed by throttling the steam supply. Frequently, however, a centrifugal pump is used for this purpose which is effective and simple inasmuch as no float valve is required.

Furthermore, the centrifugal hot well pump is more reliable than a reciprocating pump. With the latter, if there is a sudden temporary fall of vacuum, the temperature of the water within the pump immediately rises. Then when the vacuum again increases, the pump at once loses its water because the water within the pump evaporates into steam at each suction stroke, preventing the pump from attaining the vacuum that is within the condenser. Under such conditions the hot well pump will not take its water until the temperature within it has by some means been reduced. In many plants where such pumps are employed cold water connections will be found leading into the interior of the pump and these are in some cases kept continually bleeding, which, of course, prevents the occurrences enumerated above. The centrifugal pump is not subject to this trouble. Failure of the hot well pump to keep the condenser empty may result in a slug of water going to the dry air pump with disastrous results.

Sometimes a tubular cooler is employed at *K,* Fig. 4, through which the air passes to the air pump and through which is led the cooling water on its way to the condenser. This is for the purpose of increasing the density of the air going to the air pumps, and condensing out the vapor of water, thus reducing immensely the volume to be handled by the air pump, in the proportions shown later.

Fig. 5 shows a different arrangement of the same system in which case the exhaust steam is led into the bottom of the condenser instead of the top and similarly, the air pump draws its air from the top of the condenser and the direction of flow of cooling water is reversed so that the ingoing steam comes in contact with the hottest cooling water and the air pump draws its air from the portion of the condenser which is coldest. In this case the cooler (K in Fig. 4) is obviously unnecessary. This arrangement is frequently very convenient as it enables the condenser to be set close up to the floor beams, as space above the condenser does not have to be left for the connection *D* and the valve *B.* This arrangement has another incidental advantage, particularly in very large condensers; where it becomes impracticable to provide a valve *B* because of its enormous size, it is possible to operate non-condensing

without any gate valve. Water will accumulate in the bottom of
the condenser if the hot well is not operated and will act as a water
seal, keeping the exhaust steam away from the condenser tubes.
In the case of Fig. 4, if no valve were placed at *B,* the tube packing
would probably be injured if the turbine were operated non-con-
densing without the circulating pump in operation. It is seen also
that the rotative dry vacuum pump is more immune from trouble
in Fig. 5 than in Fig. 4, particularly if the air pump in Fig. 4 is not
placed higher than the condenser and if the hot well pump should
fail to maintain the condenser free from water. In the case of Fig.
5, the whole condenser may fill up before water will be drawn over
into the dry vacuum pump, whereas in Fig. 4 this will take place
with a very small accumulation of water.

Another slight advantage of the type shown in Fig. 5 is a
thermal one and is that the hot well water is necessarily hotter than
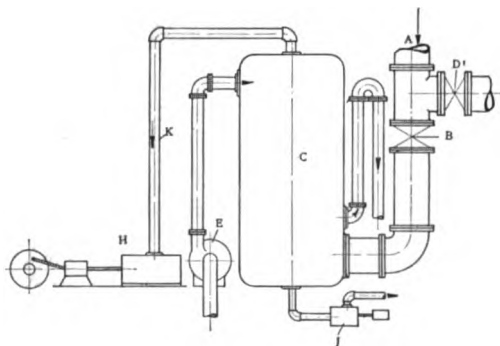
FIG. 5—VERTICAL CONDENSER WITH TOP DRY AIR
PUMP CONNECTION

in other types, as it is at the temperature of evaporation correspond-
ing to the pressure of the exhaust steam. This advantage, however,
is less with high vacua. For example, with 28 inches vacuum this
temperature would be 102 degrees; with 26 inches vacuum, 126
degrees.

A contention is made that this type of condenser is not as ef-
fective as though steam were admitted to the top and the air ex-
tracted from the bottom, the argument being that as the weight of
steam is about 63 percent of the weight of air at the same pressure,
the air will be at the bottom and cannot be advantageously ex-
tracted from the top. As a matter of fact, however, the steam and
air are so intermingled in the condenser by the dynamic effect of
the steam rushing in that this argument does not carry much weight.

At all events the writer's observations have never led him to believe there is anything in it and, in fact, there is a counter-argument for the arrangement (shown in Fig. 4) that the air pump is more effective in drawing from the top of the condenser by reason of the counter-current principle involved, which will be made clear in another discussion in connection with jet condensers.

Fig. 5 shows the arrangement of a vertical type condenser which has been used more in Europe than here, chiefly in locations where the cooling water is corrosive or muddy. For a given capacity more surface is required in such condensers because the cooling surface in a vertical tube is not as effective as though it were horizontal. It is supposed that corrosion takes place mostly when the condenser is out of service. Hence when the tubes are vertical they may be drained readily. So long as they are horizontal it is almost impossible to drain them, as water will stand in places where the tubes sag.

In concluding the discussion of surface condensers, the writer does not wish to be understood as in any sense prejudiced against their use, as they are imperative in certain locations and are the only means of obtaining a closed system for the complete exclusion of air.

The question of the location of the cooling water with reference to a surface condenser is the same in all the types discussed. Where the water is discharged to the same level as that from which it is drawn and this level is only 15 or 20 feet below the top of the condenser, the work done on the water will be only that of overcoming the friction of·the pipes and tubes of the condenser. The cooling water system will be nothing but a siphon with the condenser at the top of the loop. However, to obtain the proper siphon and if there is to be no work done on the water other than overcoming friction, the circulating water system must be free from air leaks and there must be little air drawn in with the water. Obviously where the cooling water is below the condenser an amount approaching the barometric water column, the work to be done on the water must be reckoned with, as well as for any different levels of inlet and outlet water. In some places where a stream is utilized, a dam may be built causing as much difference of level as the topography of the location will permit. If the cooling water is taken from above the dam it will give enough head on the siphon to decrease quite materially the power required in pumping.

<div align="center">*(To be continued.)*</div>

ENGINEERING RESPONSIBILITY*

AN INQUIRY AS TO THE CAUSES OF FAILURE AND METHODS OF IMPROVEMENT
CHAS. B. DUDLEY

FEW fields of study are more fruitful of results and lead to more genuine progress than a study of the causes of failures. Such studies may be unpleasant and disagreeable, they may at times be even disheartening, but the man who would make substantial advances must heed the lessons which his failures teach. It is true that valuable information can be obtained likewise from a study of materials which have given successful service. And ofttimes, when attacking a new problem, a comparison of the properties and characteristics of those parts of a structure which have behaved well in service with the characteristics and properties of those which have failed in the same service, is a most satisfactory method of approach. And yet, it is doubtful whether the study of failure does not give the more positive information. When an experiment or a construction has proved successful, we are naturally most interested in the result, and do not usually spend time and thought and study over the details which have led to our success. On the other hand, if our experiment or construction is a failure, the cause of the failure is immediately sought for, every detail is questioned, and it is this study of the details which broadens our knowledge.

WHO IS RESPONSIBLE?

Closely connected with the query as to the cause of failures is the ofttimes more important question, who is responsible for the failure? If the matter in hand is an experiment which we are making for our own information, the question of responsibility is small and is practically swallowed up in the cognate question of the cause of the failure. But if, on the other hand, the failure involves the loss of human life or the destruction of valuable property, the question of responsibility may be very grave. And if we may trust our observation, the location of the responsibility for failure is not always an easy matter.

In our studies of failed and broken parts in connection with our work at Altoona for now some years, we have been gradually led to ascribe failures to one or more of the four following causes, viz.,

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*Condensed from the annual presidential address delivered before the American Society for Testing Materials, June 29th, 1909.

to bad material, bad workmanship, bad or faulty design or to un-
fair treatment.

<div align="center">BAD MATERIAL</div>

Material is bad, and may justly be charged with being the
cause of failure when it is different from what those who put it in
service had a reasonable right to expect it to be. A rail with a bad
pipe in the head, an axle made from a badly segregated bloom, a
piece of concrete in which the materials are improperly mixed or
contain not enough or inferior cement, are all examples of bad ma-
terial, and if failure comes the failure may justly be charged to
the material.

Factor of Safety—The query may naturally arise here, ought
not the factor of safety employed to be sufficient to care for the
uncertainties of material, so that the total output of a works could
be made use of in service. Undoubtedly there is a necessary rela-
tion between the factor of safety and some of the uncertainties of
manufacture, but it can hardly be allowed that the producer should
then throw upon the consumer all the uncertainties of material.
We cannot help thinking that our definition of bad material is
sound, viz.: Material is bad when it is different from what those
who put it into service had a reasonable right to expect it to be. If
the material is bought on specifications, it is reasonable that it
should be what the specifications call for. And even if it is bought
on indefinite, verbal or written order, such material should be sup-
plied as the buyer had a reasonable right to expect would be fur-
nished. But why is there ever any difficulty between the producer and
consumer about material? The price is agreed upon when the or-
der is taken and the quality of the material is either specified or un-
derstood. Why, then, does not the producer always furnish good
material?

Price Factor—First and perhaps most important is the price.
It is constantly urged that the consumer will not pay the price
requisite to secure the materials desired. No information is usually
given as to how far the wished-for price, requisite to secure such
good materials as the producer would like to furnish, covers a de-
sire for large profits and consequently consumers have always been
a little slow in attaching much weight to this excuse. Prices are
largely determined by competition, and in the absence of some-
thing more than a verbal statement from the producer that better
materials would be furnished at a higher price, he would be a bold

purchasing agent that would pay the higher rate. On the other hand it is undoubted that competition is the antagonist of quality, and where materials are bought without reasonable specifications rigidly enforced there is unquestionably much weight in the contention of the producer.

Another Excuse—Another reason or excuse for poor materials is that processes and methods of manufacture do not always and every time yield the desired first quality product. Strive as the manufacturer may, the works always turns out some material that is inferior. Taking one illustration from the steel industry, it is well known that every heat is not equally as good as every other, and that a part of each ingot is inferior to the remainder of it. Of course, all of this inferior part that cannot be sold must necessarily remain as scrap, to be worked over again, with the result that the manufacturing cost of the marketable product is necessarily increased. Hence the tendency to crowd the limits and force upon the purchaser all the merchantable material possible, even though some of it may be inferior.

Functions Usurped—Another and most pernicious excuse for furnishing bad materials is the attempt so common on the part of producers to usurp the legitimate functions of both the consumer and his expert. This manifests itself in the statement, so commonly made by those furnishing material, that it is good enough for the purpose, thus arrogating to themselves the right to decide not only how the material shall be made, but also what kind of material the consumer and his engineer shall use. Pernicious though this custom may be, a good deal may be said in palliation of it. The practice is the outgrowth of an historical situation. In the earlier days, when the consumption of materials was only a fraction of what it is at present, the producer of any material was supposed to know not only how to manufacture it, but also its characteristics and how it would behave in service, and consequently consumers who in those days had scarcely begun to study for themselves the behavior of materials in service, naturally turned to the manufacturers for counsel as to what materials to use. This practice is still in vogue, and it is to be confessed that, where it is employed, no legitimate criticism of the producer can be made if he urges that the material is good enough for the purpose. On the other hand, as time progressed, and large consumers began to study for themselves the behavior of materials in service, as they began to employ their own experts, as testing machines and laboratories began to increase, as,

indeed, a society for testing materials came into existence and knowledge of the properties and characteristics of materials began to widen, it is evident that the situation has changed and that where materials are bought on definite specifications, the voice of the producer as to quality is no longer potent, and that the old excuse for inferior materials, that they are good enough for the purpose, is no longer entitled to consideration or weight. We are entirely ready to allow that the study of materials, during both the process of manufacture and their behavior while they are in service, is a legitimate field of activity for both producer and consumer, and that while specifications are being made there should be the heartiest co-operation on the part of both; but the specification having been decided on and the contract placed in accordance therewith, there really seems to be very little room left for excuse for furnishing materials that do not meet the requirements, because they are, in the judgment of the producer, good enough for the purpose.

BAD WORKMANSHIP

That bad workmanship is a far too frequent cause of failures is common experience. The tendency to slight the job is almost universal. A rivet or a bolt is left out, with consequent increased strain on those which are actually put in, a forging does not fill out the pattern, or the metal is burned, or a weld is defective. We knew a case once where the construction on a passenger coach involved the safety of human life, and where the drawings required that there should be two nuts on a bolt and the end of the bolt riveted over. After the cars had been in service a few weeks and some minor repairs were being made, it was discovered that the bolts originally used in a number of the cars were too short, that the second nut only grasped one or two threads, and that the remaining space in the nut had been filled with putty, so manipulated and stained as to give the appearance of the riveted end which the drawings called for. There is little doubt that the experience of each of you will furnish quantities of cases of bad workmanship, and we have known engineers who did not hesitate to declare that bad workmanship was the principal cause of failures in service.

No doubt many will claim that inferior or insufficient compensation is the most fruitful cause of poor quality of work at the hands of those who, in our industrial system, play the part of hewers of wood and drawers of water. But if we are right, the experience of the last few years has not seemed to confirm this view. If this was

the real explanation it would seem to necessarily follow that voluntary increase in wages would bring an increase in efficiency. On the other hand, if we may trust the indications that we have been able to gather, the increase in efficiency following voluntary increase in wages has been most disappointing. We must apparently look further for the real reason for poor workmanship.

Matters of Compensation—In our judgment, the method of compensation for work performed has a direct and most important influence on the quality of the service rendered. We refer especially to the piecework system in those places where it is applicable, and to the payment of all interested in proportion to the amount of successful output, which is so common in the steel industry. Both these methods of compensation stimulate output at the expense of quality, and it is not at all strange, perhaps, that after constructions have found their way into service, we should not infrequently find evidences of the haste, the slurring over, and the inferior workmanship which these methods have necessarily done so much to stimulate. We are not at all prepared to suggest any substitute for them, and we are, and have been for many years, an advocate of them from the standpoint of successful management; but it is folly for us to close our eyes to the fact that the piecework and other successful output methods of compensation of workingmen are antagonistic to quality of work, and that, despite all our efforts to the contrary, they may justly be held responsible for some of our engineering failures.

DESIGN

It is evident that the engineer who makes or finally decides upon the design of any structure carries a heavy load of responsibility. He is first in the field and practically tells all who follow what is to be done. He must decide not only the kind of material that is to be used but also the amount or sizes, and how it shall be disposed. His realm embraces every kind of structure, from the foundation of a bridge or building to the most minute detail of a locomotive or car. His knowledge of the properties of materials used in construction must necessarily be broad and comprehensive.

Two Difficulties—The engineer who makes the design labors under two very serious difficulties. First, it is not possible, many times, to compute the strains to which the whole or parts of the structure will be subjected. Perhaps we can make this point clear best by considering the locomotive driving axle. The strains produced,

when we regard the locomotive as a vehicle, are simple and easily determined. So likewise the bending moment produced by the action of the steam on the piston, as well as the torsion strain produced by the crank. But who can tell the bending moment produced by the lurch when the wheel strikes a curve at high speed? Who can even give a guess at the strain produced when the brake is applied, making an emergency stop at 60 miles an hour? Moreover, the tendency of the times is toward larger and larger structures. And as the parts increase in size, would any of us be willing to say that the strains in each part would increase directly proportional to the increase in size of the whole structure, or that a proportional increase in size of any given part would so successfully meet the increased strains as did the corresponding smaller parts of the original structure? The engineer who makes the design, perhaps more often than any of us, is at the end of his knowledge, and if failure comes, due to defective or faulty designs, deserves in our opinion, more sympathy than any one else involved.

Designer's Troubles—But the designer labors under another serious difficulty. He is often overruled and prevented from doing what his judgment prompts him to do, in the interests of safety, by those who control expenses. The construction he would like to use costs more, and the management for economic reasons demands something less expensive. Of course, under these conditions much responsibility is taken off the designer. And while we are ready to allow that some check is desirable, since those who make the design are, after all, human and naturally will take care of themselves, we cannot but feel that this check should be sparingly applied in all places where safety to human life is involved.

UNFAIR TREATMENT

As already indicated, there is a natural disposition on the part of each of us to relieve ourselves from blame and put the fault on some one else, and if our observation is worth anything there is no field of parceling out desserts among those involved in failures and the responsibility therefor, more fertile than this one of unfair treatment. If a rail breaks or fails in service there was, says the rail maker, something wrong with the track or with the locomotives or cars that run over it. If a car wheel breaks or fails to give the guaranteed mileage, the track was too rough, the use of the brakes too severe, or the loading too heavy, and so on. Far be it from us to say that unfair usage is not many times a legitimate explanation

of failures. If a freight locomotive, designed to haul a heavy load at 20 miles an hour is used at times on a passenger train at 40 miles an hour, and in so doing shakes herself to pieces, the fault is certainly not in the materials, nor in the workmanship, nor in the design, but in the unfair use. These examples might be multiplied to almost any extent, but perhaps enough has been said to make the point clear.

There is, however, another phase of this part of our subject. Unfair treatment is very much broader than the obvious misuse of a bridge or of a moving vehicle. The materials entering into a structure may be unfairly treated. If the calculated strains are too high, or, what amounts to the same thing, too low a factor of safety is employed, materials are unfairly used. Still further, where a structure is a composite it may, and undoubtedly does, often happen that the elements making up the composite are unfairly treated, as when for economic reasons, not enough money is spent to properly install the structure. For example, a steel rail called upon to do its work supported by too few ties, insufficient ballast and a badly drained sub-grade, is unfairly treated. Moreover, the state of repair in which structures are maintained is clearly an element in their fair treatment. If not enough money is spent in repairs and parts become weakened by decay, corrosion or wear to such an extent that failure results, it is entirely obvious that the failure must be attributed to unfair treatment.

Rail Failures—It will be remembered that within the past two or three years there has been pretty much outcry in regard to broken steel rails, and the steel rail manufacturers have, in the technical press, been quite severely called to account for their shortcomings. Indeed, from this platform, in the last annual address, some statements were made indicating that it was believed that the maximum fiber stress in the 100-pound rail under present conditions of wheel loads and speed was not over 12 500 pounds per square inch. Some two months ago we received a letter from one of the ablest metallurgical engineers connected with steel rail manufacture in this country, in which this statement was very seriously called in question. The writer of the letter figured that under many conditions the fiber stress might be double the figure given, and under extreme, but still possible, conditions the fiber stress might reach nearly four times this figure. The obvious conclusion was, although this was not

stated in the letter, that it was these extreme fiber stresses, this un-
fair treatment, which caused the rails to break.

We may further note the experience of the Atchison, Topeka &
Santa Fe railroad with broken rails on different sub-grades. This
road has some 227 miles of roadbed which were sandy, porous and
well drained, and 91 miles which were largely clay of a kind that
holds water. The traffic was the same over both portions and the
rail all 85-pound rail. The rail breakages in one year were two and
a half times greater per mile of track on the clay sub-grade than
they were on the sandy sub-grade. Mr. Wells, the general manager
of the road, was kind enough to say, in communicating this informa-
tion, that these facts seemed to confirm the statement made in last
year's annual address that "there are indications that rail failures
are a question of geography." More to the point for our present
discussion is the obvious conclusion that the use of rails on clay sub-
grade full of water without sufficient porous ballast is unfair treat-
ment, and that breakages under such conditions, cannot justly be
said to be the fault of the rail.

It is difficult for us to see how any one who is responsible for
safety in structures dare at the present time put material into these
structures which has not been bought on carefully prepared speci-
fications, and which, before acceptance, has not been rigidly inspect-
ed and tested. In time past, before consumers understood the de-
mands which the service makes on materials, the reputation of the
maker was perhaps the best safeguard known for good materials
and was accepted as reasonable defense in the investigation follow-
ing disaster. But in these days, when the service has been so fre-
quently questioned, when so much accumulated information is
available, when experts and facilities for testing are so largely mul-
tiplied, we cannot help feeling that the management that puts ma-
terials into service, especially where safety is involved, without care-
ful and conscientious inspection and testing, is taking a risk that
it is no longer entitled to assume. It is gratifying to be able to see
that, as the years go by, there is a constant and steady growth in
this field. And while the ground is still far from being covered and
the number of standard specifications still far too small, each year
brings some progress, some steps forward.

Necessity of investigation—Bad workmanship and bad ma-
terials can apparently be so controlled as to secure safety by suf-
ficient supervision and by having proper specification, with rigid
inspection and test. But how about the unfair treatment of ma-

terials, or the structure made from them? Here no supervision beyond some meager legislative enactments and the condemnation of public opinion in case of disaster are possible. It is, of course, true that those in charge of the construction and operation of utilities in which the public safety is involved are constantly face to face with the possibilities of heavy losses in the way of damages for accidents, and no doubt this is a most powerful check against unfair treatment. But it has seemed to us for a long time that the producers of material have far too much neglected their opportunities. Surely it is as legitimate that the producer shall study the treatment his material gets in service as that the consumer should study the methods by which that material is made. It may take the consumer a few years to become familiar with the idea of being told that he has not treated material fairly, since he is undoubtedly accustomed now to thinking that he can do what he wishes with what he has bought and paid for; but we are confident there would have been fewer complaints of material in the past if the method we have suggested had been in vogue. It is common experience that the truth is reached with much greater certainty and speed if a problem it attacked by two parties who approach it from different standpoints and are actuated by antagonistic interests.

What shall we say of the engineer who makes the design? We have already described his difficulties, pointed out his limitations and expressed our sympathy with him in his chance failures. The truth is we are using materials in construction without sufficient knowledge. There is crying need for experiment. The factor of safety everywhere is largely a guess. We cannot help feeling that no better use could be made of some small fraction of the millions that have been accumulated by individuals in connection with our great industries during the past half century than in the establishment of a bureau of engineering research. Who will avail himself of this magnificent opportunity?

Just a word in conclusion. No one can contemplate the situation which we have been trying to discuss without being impressed with the diverse and ofttimes antagonistic interests involved. The producer of material is anxious to secure the largest amount of successful output and the greatest possible amount of reward therefor. The consumer wants to limit this by restrictions as to quality and to obtain the material at the lowest possible figure. The workman's interest is to secure the maximum of pay for the minimum of effort, and in this struggle it may perchance happen that the quality

of work suffers. The employers' interests are clearly the reverse of the workman's, and so on. The foundations of these diverse interests are of course very deep, and with the present organization of society it is not easy to see how they are to be obliterated or their antagonism neutralized. But we beg to make one suggestion. Would not an infusion of genuine conscientiousness into our industrial life bring an amelioration? If a little less energy were expended in the mad race for wealth and a little more zeal manifested in maintaining the rugged virtues of honesty, integrity and fair dealing, would not some of the friction and contention of our present commercial life disappear? We must all live together, and surely harmony is better than contention. There are some things in life of more value than money.

APPLICATION OF INDUCTION MOTORS IN CASCADE CONNECTION

AS COMPARED WITH SINGLE MULTI-SPEED INDUCTION MOTORS

H. C. SPECHT

A S it is very difficult to give exact rules for the practicable and economical use of cascade sets, it is preferable to consider the principles of their application by means of specific examples.

Example 1—Assuming that a two-speed application is under consideration, the speed ratio being 1 to 2 and the motors to have polar-wound rotors, the normal load being several thousand horsepower and the line voltage high; assuming further that the conditions of operation require changing over continuously from one speed to the other at very short intervals, and that the safe operation without any interferences is of the greatest importance. A cascade set is very desirable, under such conditions, although the cost would be higher than that of an ordinary two-speed motor.

The control is very simple and safe, and the connections for the set would be arranged as shown in Fig. 3 of the preceding article.* The speed can be changed very rapidly with this arrangement, without handling large currents of high voltages. Hence, the contacts

*See THE ELECTRIC JOURNAL for July, 1909, p. 426.

of the switching apparatus are not subjected to severe service and do not need to be repaired often.   Further, the line circuit as well as the other main circuits of the set are not disconnected while the speed is being changed; thus, high surges in the line are prevented. It may be of importance also, to have two motors so that in case of a break-down in one, the other motor can serve to keep up operation at its speed for a certain period, a feature which may prove very satisfactory in case of an emergency.

Since the speed ratio is 1 to 2, an ordinary two-speed motor with a single winding might be applied.   Although this arrangement would be cheaper, as mentioned before, it has the serious disadvantage that the main circuits have to be opened and closed while the speed is being changed.   This can be overcome somewhat by various means, which, nevertheless, add considerable complication to the control, thus making safe operation somewhat doubtful, as failure of any one of the various switches might cause serious trouble.   On this account, such an outfit might prove more expensive in the end. It is clear that, with such complicated means of control, change of speed cannot be accomplished rapidly.

Another way of overcoming the opening and closing of the primary circuit on a two-speed motor is to build the primary of the motor with two separate windings.   In this case both of these windings can remain connected to the line; nevertheless, the connection of the secondary circuit has to be changed, no matter whether it consists of a single two-speed winding or of two separate windings.   It should be noted also, that by having both primary windings connected permanently to the line, the entire magnetizing current flows through each winding, resulting in higher copper and iron losses and lower power-factor.   On account of the higher losses and the greater space necessary for placing the two windings a larger motor is required.   Even if the cost of this larger motor were lower than that of a cascade set, the low power-factor and the low efficiency would give less economical operation than the cascade set, and the complicated control and windings cannot by any means be considered as safe as the arrangement given by the cascade set for the conditions specified in this example.   Considering the cost of repairs and the profit on the work which could have been done during the time required for making the repairs, it is very clear that the initial cost of a motor may often be a small consideration compared with the importance of securing safe and continuous operation.

Example 2—Considering another two-speed proposition of the

same characteristics as in the preceding except that the speeds in this case are to be in a ratio other than 1 to 2 and differing greatly from the ratio 1 to 1. For a proposition of this kind a cascade set may be used to advantage, and the cost may be but little more than that of a two-speed motor for like service. For instance, if at the high speed the output is great as compared with the output at low speed, the cost of a cascade set does not differ greatly from the cost of a corresponding two-speed motor, the difference in cost being less and less, with increase in the difference between the outputs at high and low speeds. Examples of such a condition of operation are found in the use of motors to drive centrifugal pumps, fans, hoists, trains, etc., in which the power required increases rapidly as the speed is increased. Assuming that, in a cascade set suitable for such an application, motor *I* has 24 poles and motor *II*, 10 poles; then the output at the speed corresponding to 24 poles should be 60 percent (or more) greater than that at the lower speed corresponding to 34 poles, (i. e., as obtained by direct concatenation). In this case, the cost of the cascade set would be nearly the same as that of a two-speed motor for which two separate windings, in both the primary and rotor, are required. Moreover, it has all the advantages of the cascade set considered in *Example 1* over the two-speed motor.

A two-speed motor consisting of a single motor with two separate windings has further disadvantages, viz., that the diameters of both the stator and rotor have to be greater than that of either motor of the cascade set, thus giving increased peripheral speed and somewhat poorer mechanical design. Also, the two separate windings required for the desired speed ratio render it very difficult to obtain a construction which is satisfactory mechanically. Furthermore, in case one of the windings requires repair, both windings may have to be removed at the particular place of the defect.

Example 3—Considering a proposition requiring two speeds, in which motors with polar-wound rotors are employed, the speeds to be in a ratio other than 1 to 2, yet not differing greatly from the ratio of 1 to 1, changes of speed not being required very frequently or quickly (in contrast to the conditions in *Examples 1* and *2*); a single two-speed motor with two separate windings would be the more practicable and also of lower cost; generally not much more than that of a single-speed motor. The coils of the two windings for each member of such a motor can be wound with the same throw, thus making it possible to obtain a good mechanical

construction, a point of especial importance in connection with the design of the rotor.

Example 4—Assuming a proposition similar to that of the last example, except that the speeds are to differ considerably from the ratio 1 to 1; in this case a single motor with two separate windings will not be as practicable as for the preceding case, since the coils of the two windings for each member cannot be wound with the same throw. The result of this will be that the windings will not be as good mechanically, this being especially objectionable in the design of the rotors of large motors for high voltages. In smaller motors in which the rotor voltage is low, the above method might be acceptable, but it is found that, where, for the various reasons previously mentioned, the multi-speed type of motor is not satisfactory, the cascade set may be used to advantage.

Example 5—Considering a three-speed proposition, two of these to have the ratio of 1 to 2, such a problem may be solved by a single motor having one single-speed winding and one two-speed winding or, otherwise, by a cascade set. The question as to which of the two schemes is the more practicable and economical depends on such conditions as the following:—If, for example, the speed corresponding to the single-speed winding and that corresponding to the slow speed connection of the two-speed winding are not too far apart, all of the coils for each member can be wound with the same throw. In this case conditions may be met satisfactorily by means of the multi-speed type of motor, provided there is no objection to using a single motor of this design because of the details of control involved thereby. It will undoubtedly prove to be the cheaper of the two types. If, however, the two windings cannot be wound with the same throw a poorer mechanical construction will be obtained, with greater liability of breakdowns; the use of the cascade set will then be preferable and will have all the advantages mentioned in the foregoing.

Example 6—In a three-speed proposition, no two speeds of which have a ratio of 1 to 2, a single motor can be used only to a limited extent as it requires three separate windings, or otherwise a single winding with a large number of leads brought out. The control for the latter would therefore be very complicated, and, with few exceptions, would prove unsatisfactory. Here, again, the simple cascade set would be practicable, or a modified form of cascade connection employing a two-speed type of motor for the second element. If, for example, speeds corresponding to 26, 30, and 34 poles are required, a cascade set consisting of one motor with 26

poles and a second motor with a two-speed winding giving four and eight poles respectively could be used. The same speeds could be obtained with two motors of 30 poles and four poles respectively, operated in direct concatenation, in differential concatenation, and as a single motor of 30 poles. However, since the speeds do not differ greatly, it might happen that, if the motor with 30 poles were connected to the line, and the set connected in differential concatenation, the slip at heavy loads would be such that the speed of the set would be reduced to that corresponding to 30 poles. The result of this would be that the speed would not return to normal value upon removal of the load without its being accelerated to the higher speed by connecting the four-pole motor to the line. To obviate such a condition, it is evidently advisable to keep the four-pole motor connected to the line when running in differential concatenation. As has already been pointed out, the losses will be considerably higher than when the 30 pole motor is connected to the line, it being difficult to keep the four-pole motor cool. For a three-speed proposition for the above speed combination or one similar thereto, to be handled by means of a cascade set, the differential concatenation should be avoided if possible, because of these disadvantages. This may be further illustrated by considering an extreme case:—Assuming that speeds corresponding to 12, 24 and 36 poles respectively, are required; the conditions might be met by means of two motors of 24, and 36 poles, respectively, in cascade, the 12 pole speed being obtained by differential concatenation. Since the speeds bear a ratio of 1 to 2 to 3, this impracticable method can be avoided by employing a cascade set consisting of a 12 pole motor and one of 24 poles. The speeds corresponding to 12 and 24 poles would then be obtained by running each motor singly, that corresponding to 36 poles being obtained, of course, by direct concatenation. In addition to the entirely satisfactory operation of this latter set, its cost would be considerably less than that of the former.

Example 7—In a proposition for four speeds, the ratio of each pair of speeds being 1 to 2, the four speeds could be obtained by means of a single motor with two separate two-speed windings and would give a satisfactory arrangement for a motor with a squirrel cage rotor, provided no objectionable features were involved in connection with the control details, construction, etc., points which have already been considered. If the rotor also is to be polar wound it should be noted that eleven collector rings will be required, a feature which would doubtless prove objectionable on account of

the complication of design and additional cost involved thereby. For all cases for which such a motor is found to be less desirable, the cascade set may be applied with good results, the methods having already been described.*

Example 8—In a proposition involving four or more speeds and having speed combinations other than those outlined in the previous examples, the cascade set is always superior to a multi-speed motor because of the fact that, disregarding all other disadvantages such as have been mentioned in the foregoing, the winding of the multi-speed motor would be so complicated as to render it entirely impracticable.

Example 9—In a proposition in which high starting torque with the lowest possible energy supply is required and for which the horse-power output increases in direct ratio (or even higher ratio) with the speeds, such as in traction or hoisting service, etc., the cascade set may be found to give very satisfactory results in every respect. This is especially true of the first of these applications where, with fixed limits for space distribution under the car or locomotive, the motors of a cascade set prove to be of the proper outlined dimensions.

In General—The nine foregoing examples do not, of course, cover all possible cases for multi-speed problems. However, by application of the principles outlined therein, it would ordinarily be found an easy matter to arrive at an opinion as to the more advisable form of motor equipment to be employed to give the required multi-speed operation.

The application of cascade sets and single multi-speed motors only has been discussed in the foregoing comparisons, these representing the two principal methods of obtaining multi-speed operation with induction motors. It should be noted, however, that there are numerous other schemes in existence which might be found practicable for application to some cases; such, for example, as mechanical speed changing devices, internal cascade motors, frequency changers, it being intended to give these consideration in a future article.

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*See ELECTRIC JOURNAL for July, 1909, pp. 422-3-4.

STANDARDIZATION OF THE NOMENCLATURE OF ELECTRIC MOTORS

J. M. HIPPLE

THE growth in the number and character of electric motor applications has led to the grouping of various motors of similar characteristics into classes. It has been found most convenient to designate these classes according to the speed characteristics of the motors. While practically all of the motor manufacturers have adopted a uniform classification and nomenclature, the motor users and general public have not had the same clearly outlined to them. The principal error arising in the nomenclature of motors is in the use of the terms "adjustable," "variable," and "varying" speed. It is only within the past few years that confusion has arisen in the use of these terms as applied to motors. When the value of motor applications first began to be generally appreciated and the use of motors increased, the distinguishing names for the various types of motor found to be desirable for the various classes of service were based upon the windings of the motor, such as shunt, series and compound-wound for direct-current motors.

Later, as the shunt and compound-wound motors took different forms, such as adjustable speed for machine tool work where a number of different speeds can be secured and at any of these speeds the motor has practically the same characteristics as at any of the other speeds, it was found necessary to use a new descriptive term. The expression "variable speed" came into very general use, the ordinary specification for a direct-current machine tool motor being "shunt-wound, variable speed." The term variable speed in this connection is manifestly a misnomer. The true variable speed or, more properly, varying speed motor, is one in which the speed variation is inherent, i. e., occurs without any external manipulation. Such a motor is the series-wound motor, whose speed varies with changes in the load. The term "adjustable speed" as applied to the ordinary machine tool motor with field control accurately describes the motor. Under full field conditions, these motors have certain speed characteristics with varying load. By means of a rheostat the field current can be adjusted so that a number of higher speeds can be secured and at each of these speeds the motor will have practically the same speed characteristic under varying loads as at the lower speed.

The speeds of alternating-current motors cannot be adjusted as

easily as can those of direct-current motors and the same confusion in the application of terms has not arisen. However, alternating-current motors and direct-current motors can easily be classified under the same speed headings and this has been done, the idea being that a uniform classification and nomenclature will be of great advantage, both to motor users and to the manufacturers.

The American Institute of Electrical Engineers has adopted a classification drawn up along these lines and the American Association of Electric Motor Manufacturers has adopted the same classification, the wording in the latter case being slightly modified for the sake of more definite interpretation as applied to existing commercial and engineering conditions. The wording of this classification as adopted by the motor manufacturers is as follows:

A.—*Constant Speed Motors*—in which the speed is either constant or does not vary materially, such as synchronous motors, induction motors with small slip, ordinary direct-current shunt motors, and direct-current compound-wound motors, the no-load speed of which is not more than 20 percent higher than the full-load speed.

B.—*Multi-Speed Motors*—(two-speed, three-speed, etc.)—which can be operated at any one of several distinct speeds, these speeds being practically independent of the load, such as direct-current motors with two armature windings and induction motors with primary windings capable of being grouped so as to form different numbers of poles.

C.—*Adjustable Speed Motors*—1—Shunt-wound motors in which the speed can be varied gradually over a considerable range, but when once adjusted remains practically unaffected by the load, such as motors designed for a considerable range of speed by field variation.

2—Compound-wound motors in which the speed can be varied gradually over a considerable range, as in 1, and, when once adjusted, varies with the load, similar to compound-wound constant-speed motors or varying-speed motors, depending upon the percentage of compounding.

D.—*Varying Speed Motors*—or motors in which the speed varies with the load, decreasing when the load increases, such as series motors and heavily compounded motors. Examples of heavily compounded motors are those designed for bending roll service and mill service, in which shunt winding is provided only to limit the light load operating speed.

The above classification and nomenclature should be thoroughly understood and adopted by every one having to do with motor applications, and in discussions on the subject, in connection with trade papers and in correspondence. In order that the classification may be thoroughly understood attention is called to one or two points that may not be entirely clear. Under paragraph *A*, it will be noted that "direct-current compound-wound motors, the no-load speed of which is not more than 20 percent higher than the full-load speed," are listed as constant speed motors. Within narrow limits such motors are true varying speed motors. It is, however, commercially desirable to designate these motors as constant-speed motors and to establish a dividing line between constant and varying speed motors, based on the percentage change in speed from no load to full load. This is for convenience in designating motors and for the purpose of calling direct attention to the dividing line between what is commonly known as standard compounded and heavily compounded motors.

Under paragraph *C* it will be noted that shunt and compound-wound motors are both placed in the adjustable speed class. In the case of the compound-wound adjustable speed motor when operating at the higher speeds, the speed characteristic is practically that of a varying speed motor. This varying speed characteristic may lead to some confusion with this particular motor, and it is, therefore, necessary to note carefully the wording of this paragraph. This type of motor is classified as adjustable speed rather than varying speed because in the majority of instances it is the adjustable speed characteristic which is particularly desired in making the application of the motor to its work rather than the increased compounding effect that occurs when operating at the higher speeds. This increased compounding effect is due to the lower saturation in the motor and the increased proportion of series field to total field, and is an incidental characteristic rather than the one for which the motor is designed.

Many motor applications can be made more intelligently if, in addition to using the classification given above, the service is described in terms of continuous or intermittent duty, and load constant or varying. In order to make this point clear, Table I has been prepared, giving one example of each of the different classes of service. Practically every motor application can be listed under one or the other of these headings.

TABLE I—CLASSIFICATION OF MOTORS 501

Constant Speed.	Continuous Duty.	Load Constant.	Fan.
		Load Varying.	Line Shaft.
	Intermittent Duty.	Load Constant.	Vacuum Pump.
		Load Varying.	Paper Cutter.
Adjustable Speed.	Continuous Duty.	Load Constant.	Paper Calender.
		Load Varying.	Printing Press.
	Intermittent Duty.	Load Constant.	Vacuum Pump.
		Load Varying.	Lathe.
Varying Speed.	Continuous Duty.	Load Constant.	Small Fan.
		Load Varying.	Bending Press.
	Intermittent Duty.	Load Constant.	House Pump.
		Load Varying.	Crane.
Multi-Speed.	Continuous Duty.	Load Constant.	Ventilating. Fan.
		Load Varying.	*
	Intermittent Duty.	Load Constant.	Fire Pump.
		Load Varying.	*

*Multi-speed motors are at present almost exclusively alternating-current motors. The classes of service in which these motors are used are limited but a considerable field may develop later.

THE ELECTRICAL AND COAL MINING INDUSTRIES*

F. C. ALBRECHT

THE electrical and mining industries are very closely related, as large gold, silver, copper, lead, coal and other mines are all being electrically operated. In many cases the mine workings are a mile or so from the surface and operators would have a hard problem to solve to run such a mine on a competitive basis if it were not operated electrically. The development of the application of electricity to coal mining has been a very interesting one. It would naturally seem that with coal direct from the mine right at hand, the cost of power would be a very negligible item and that boilers, engines and generators could be located wherever power is needed. The increasing size of mines and the consolidation in their ownership have resulted in a careful investigation of the various possible economies obtainable by the application of electricity to mining work. It has been found in a large number of cases where a mining company operates a number of mines in the same locality that it is desirable to have a central power station to supply all electrical power needed in the entire district covered by the mining operations and to distribute the power to the different mines from sub-stations located at each mine or center of distribution.

A well known engineer connected with one of the large coal mining companies of West Virginia has very adequately summed up the advantages of a central power station and its sub-stations for mines as follows:

1—Minimum outlay for copper.

2—Maintenance of good working voltage.

3—Flexibility in mining operations.

4—Expensive foundations are not required at sub-stations.

5—Water and fuel are not required at sub-stations.

6—Adaptability for lighting at remote places together with local lighting.

7—Permits the use of high voltage alternating-current motors.

8—Reduces number of station employes and consequently affects the labor expenses.

9—Low cost for oil and waste.

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*Condensed from a paper read before the West Virginia Coal Mining Institute.

10—Capacity may be less than combined capacities of a number of small direct-current stations.

Each and every one of the above are distinct advantages.

It is also found that continuity and reliability of service are increased by having the central power station separate from the mining equipment, located in a desirable place for the generation of power, equipped with the most reliable and efficient generating machine and operated under the direction of expert engineers. By the use of the alternating-current transmission system the expense for copper is cut down, high speed steam turbo-generators of comparatively small size may be used, the power equipment at each mine consisting only of a rotary converter sub-station. These stations can be moved with small expense as compared with boilers, engines and generators requiring heavy foundations. The sub-station equipment requires little expert attention and is nearly automatic. It is also possible to use direct-current for the mining locomotives and alternating-current for the pumps, fans, etc.

In the mine proper there is the electric locomotive, or "electric mule," as it is sometimes known, with which all mining men are more or less familiar. The "electric mule," after the day's work is done, does not require any oats or hay, and is ready to go to work at any time.

At present there are three classes of electric mine locomotives, the first being the regular haulage locomotive, generally of from eight to 20 ton capacity. There are, of course, locomotives of over 20 tons capacity, but generally it is better practice, where conditions will permit, to have two 10 ton or even two 13 ton locomotives, which are operated either separately or together in tandem arrangement. Too heavy a locomotive involves very heavy iron for the track, and it is often unwieldy and inefficient.

Second, there is the gathering locomotive known as the "reel" type. With this locomotive, gathering is done by means of the locomotive going into the rooms, pulling out the "loads" and pushing the "empties" back in, the reel being used to connect the locomotive with the electrical circuit back in the main part of the mine. These reels are furnished with either single or double conductor cables, depending upon the local conditions in the mine.

Third, there is the gathering locomotive known as the "traction reel" or "crab" type. This locomotive does not go into the rooms at all, but the end of a wire cable wound on a reel on the locomotive is pulled into the room and fastened to the loaded car, which is then

pulled out by winding the cable on the reel, which is usually operated by means of a separate motor on the locomotive with its equipment of controller, resistance, wire and other details. This type of locomotive is now being built so as to use one of the main hauling motors of the locomotive for gathering also. This is accomplished by having a clutch arrangement which throws the reel or crab so as to operate with one of the hauling motors. The clutches are independently controlled and therefore the operator can drive the locomotive only if desired or the reel or crab only, or he can drive both the reel and locomotive together at one and the same time. A foot brake is also applied to the reel drum shaft so that a car being hauled by the wire rope can be held on the grade if desired. Both forms of gathering locomotives are also being built with further modifications, and are equally adaptable.

As regards the cost of operating with electric haulage it is obviously difficult to give exact figures which will apply in all cases, but it has been found that electrical haulage is considerably cheaper than animal haulage. The life of the locomotive is longer than that of the mule, there being locomotives in actual service to-day which were installed ten or twelve years ago. Against this, two or three years is the average life of a mule in a mine. The length of the haul and speeds required are also very much in favor of the locomotive. The electric locomotive does not run up a large feed bill. It is not shocked and consequently hurt by coming in contact with wires. The locomotive does not require anywhere near the attention that a mule does. In fact, in a good many mines, the locomotive is given practically no attention whatsoever, until something breaks down. As a general rule, if any piece of machinery is abused, it is the electric mine locomotive. As long as a locomotive will move, car after car is added to the trip, until something has to give away.

The motors used for the operation of mine ventilating fans must be perfectly reliable, as on the successful operation of these, depends the lives and efficiency of the men inside of the mine. Good air and a proper supply of it is required, and the fan is therefore depended upon to furnish this. The writer was recently told by a prominent mine manager, that only once in the last five years has he had to call his men out of the mine on account of trouble from electrically-driven fans. As regards the form of drive for fans, whether the fan should be geared, belted or chain driven, that should

be carefully studied in each instance. In some cases one form of drive gives the best results, in another instance another form of drive is preferable. Where there is a great fluctuation in voltage, either a belted or chain drive is desirable. If floor space is an item, the chain drive may be the best method. If the voltage is constant and good regulation secured, then a geared fan is proper. Direct-coupled fans can also be considered and some of these are in actual operation. The form of drive selected should, however, in each instance, be carefully considered and local conditions studied, in order to select the proper equipment. Variations in speed can be obtained by either variable speed motors or in the case of belted machines, by different pulley combinations.

Electric hoists may be operated either by direct or alternating-current motors. Likewise, there are also electrically driven cutters and punchers; also large numbers of motors for pumps from one horse-power up to even 800 horse-power capacity that are day in and day out working away, connected to pumps of every description.

Again, in addition to the use of electricity as a source of power, it is also used for lighting. It is not only used for lighting the mines, but also to furnish light for the offices and various other buildings about the mines; and in many cases, current may be furnished for lighting towns, located near mines and in this way an additional source of revenue secured.

With reference to the voltages employed, as far as alternating-current transmission voltage is considered, almost any standard voltage from 2 200 volts up is perfectly practical.

As regards the direct-current voltage in the mines, there has been and still is considerable discussion. Many are of the opinion that the voltage should not exceed 275 or 300 volts. On the other hand, others consider 550 to 600 volts not excessive. With the higher voltage, there is a great saving in copper and also in most cases a better working voltage is maintained. Looking at the question from the standpoint of safety, it is true the high voltage can give a more dangerous shock than the lower. But the point is to keep away from the wire. Especially in high coal this should easily be arranged. In many intsances, the trolley wire can be placed from four to seven feet above the rail and should always be placed from four to eight inches to the outside of the rail. With ordinary precaution this should be entirely safe. Where the coal seam is low, it might be considered proper to use the lower voltage, although it is by no means considered absolutely necessary. Some operators

consider the higher voltage safer than the lower, their argument being that the men get familiar and careless with the lower voltage. On the other hand, they have considerable respect for the higher voltage, and are more careful and have less accidents.

The writer does not believe that any iron clad rule or law should say that the operators must use either the higher or lower voltage. This would be entirely wrong and arbitrary. There are arguments in favor of both, but he does contend that in each instance, a careful inspection should be made and careful consideration given to each individual case. Local conditions will largely determine what voltage should be installed. Furthermore, no matter whether 250, 275 or 550 volts is used, the wires in mines should be uninsulated. The insulation will not last in a mine as it deteriorates rapidly and becomes a menace instead of an additional safeguard. The wires should be bare and every one operating in the mines given to understand this, in order that proper precaution and care be taken.

A system of wiring that meets with much favor where conditions are favorable is the three-wire system. By this means 550 volts can be taken from the generator or rotary converter and divided in half, using two circuits of 275 volts each. In the first installations of the three-wire system, it was necessary to use two generators connected in series, having the neutral wire joined to the common connection. This necessitated having two generators in service at all times, regardless of whether there was a large or small load. A three-wire generator is now used which gives the same service as the original scheme of having two machines. Another result of the use of three-wire generators is an increased efficiency, as one large generator has a better efficiency than either of two smaller ones.

The three-wire system is not confined to generators alone, but can also be used in connection with rotary converters in sub-stations. By means of the three-wire system, it is possible to use 550 volts for the stationary motors, such as pump motors and 275 volts for the locomotives; considering the track as the neutral and return.

A special study of the conditions at any one installation will generally result in a determination of the best system to install. It would be a great improvement, however, if there could be adopted some well defined rules governing the installation of electrical apparatus in mines. It is well known that in order to get the best results out of any business, standardization and system are necessary

and without certain rules, regulations and system, the highest efficiency cannot be obtained. Therefore, the sooner mining and electrical men get together and adopt a system of standards mutually agreeable and understood, the better it will be. Some steps have already been taken in this direction. At the last meeting of the American Mining Congress in Pittsburg, a resolution was passed authorizing the appointment of a standing committee for the purpose of standardizing as far as possible and investigating mining practice and making necessary recommendations for electrical work in the mines. This standardization can indicate, not only such matters as the voltages to be employed in the mine, but can be followed out further, for instance, in the standardization of the gauges of the tracks in the mines. So that instead of having almost every conceivable track gauge as at present, the gauges in use could be reduced to some three or four standard gauges. This would certainly lead to more interchangeability of equipment between different mines and operations than is the case at present.

The improvements and developments in electrical mining equipments have had the very beneficial effect of bringing into the mining industry a higher and better class of men in charge of the various electrical and mechanical equipments. It was previously considered that a fairly good armature winder or repair man had sufficient ability to be placed in charge of the electrical and mechanical departments. It is now rapidly being recognized that with the growth of these equipments, there must also be a growth in the capabilities of the men in charge. Consequently trained men, engineers, men who not only keep their equipments in good condition, but also have continually in mind the reduction of the cost of operation, are in charge, or are rapidly being put there. The growth of electrical operation in coal mining has brought some of the best consulting, designing and operating electrical engineers into this field. The result has been that the electrical equipments of our best up-to-date mines are as good as those to be found in any other industry.

THE JOURNAL QUESTION BOX

283—SPRAYER FOR ELECTRICAL MACHINERY—Please give details of construction and operation of paint sprayer such as used for painting the windings of generators and motors. Please give air pressure and kind of insulating paint used. W. S. D.

A double nozzle is used, one part of which is connected to a compressed air supply line, the other leading to the can holding the paint or varnish. Upon turning on the compressed air the liquid is drawn from the can by the suction of the air which at the same time serves to break up the liquid into a spray or mist. It is necessary to use a comparatively thin solution of the liquid for satisfactory operation of the apparatus. In one case 80 pounds air pressure is used; however, the apparatus can doubtless be adjusted to operate satisfactorily on various other pressures which may be available. There are numerous insulating liquids and paints available for this purpose, consisting principally of varnish, shellac and suitable coloring matter, which are advertised in the trade papers and engineering journals, detailed information regarding their properties and use being obtainable from the manufacturers. C. B. A.

284—VOLTAGE REGULATION — Please give a brief explanation of the operation and connections of voltage regulators such as would be used in a central power station where the power is transmitted by alternating current to supply a load consisting of street railway and mine machinery and which is extremely fluctuating. The regulator would be used to keep the entire station voltage constant. I have not seen anything in the JOURNAL relating to this kind of apparatus.

A standard type of induction regulator is described in article by Mr. Geo. R. Metcalfe in the JOURNAL for August, 1908, p. 448. With this method, regulation is obtained by raising and lowering the voltage as the conditions may require, through transformer action in the regulator. In the JOURNAL for September, 1908, p. 503, a method of voltage regulation is described in which a relay is employed to vary the excitation of the field of the alternator by regulation of the exciter field. For sudden fluctuations of considerable magnitude the latter method will give closer regulation.

285—END STAYS ON SQUIRREL-CAGE INDUCTION MOTOR—I have noticed that in the rotor of a three-phase squirrel-cage induction motor there are three bars extending from the rotor core to the end rings, to which they are securely fastened and placed at intervals of 120 degrees along the periphery. What is the purpose of these bars? S. S.

These serve as distance pieces to hold the squirrel-cage winding in position relative to the rotor core. Without the use of some such device there would be nothing to prevent the rotor winding from sliding out of position when subjected to the mechanical stresses due to sudden changes in load, except the friction of the bars in the slots, which alone would not be sufficient. These end stays have nothing whatever to do with the electrical operation of the machine. A. M. D.

286—USE OF BRACES ON ROTOR OF IN-
DUCTION MOTOR—The rotaries
of Western Electric type CS
induction motors are provided
with several metal pieces riv-
eted to the end rings, presum-
ably to keep the bars from slid-
ing in the slots. As arranged,
they evidently ground the rotor
winding to the iron core. Why
are these clips made of con-
ducting material, and how are
tests for grounds to be made?
One of our motors recently
burned out as a result of being
operated on heavy overload, the
rotor windings being so hot
that the solder at the ends of
the bars was melted and
thrown on the stator winding
and the insulation on the rotor
bars was so charred that a
general ground resulted. Upon
again starting the motor there
was heavy sparking between
the rotor and the stator. What
was the cause of this?   C. A. M.

It is not customary to have a squir-
rel cage winding completely insu-
lated; in fact, the general practice is
to ground the rings through the dis-
tance pieces or supports.   This is not
done for any electrical reason but
simply to stiffen the winding and, as
a few grounds do not cause any trou-
ble, no attempt is made to insulate
the supports. Smaller motors are
ofen made with insulated bars. There
is no reason for arcing between sta-
tor and rotor; it was probably due to
rubbing of the two elements or else
the rotor winding sparked on account
of loose contacts and its rotation
made it appear to occur between the
two elements.   G. H. G.

287—AGEING OF PERMANENT MAG-
NETS—In making permanent
magnets I have tried material
of all degrees of hardness but
have not succeeded in obtain-
ing magnets which are perma-
nent.   Please give the usual
method of making permanent
magnets. Do the cross-section
and form have any effect?
The magnets of automobile
magnetos are constructed of
wide laminations or sections
about one-fourth inch thick,
and usually with three sec-
tions, each section being com-

posed of two magnets placed
one outside of the other.   I
have made magnets for simi-
lar work using six sections,
each section being a solid mag-
net, the cross-section of which
is three-fourth inch by three-
fourth inch; however, they
are not as strong as they
should be.   W. P. F.

In order to obtain satisfactory re-
sults in the manufacture of perma-
nent magnets, it is essential that the
steel used should be of the proper
chemical   and   physical   properties.
Full information regarding the kind
of material required and the treat-
ment necessary will be found in
Metallographist, 1898 (obtainable in
most public libraries), in which ap-
pears a series of articles by Mme.
Curie, the discoverer of radium, on
the "Magnetic Properties of Hard-
ened Steels." The methods describ-
ed therein are, in general, those used
by various electrical manufacturing
concerns.   See reference to ageing
of magnets in article on "Integrating
Wattmeters," by Mr. H. Miller, in
the JOURNAL for October, 1907, p. 590.
                                    P. M.

288—OPERATION OF ROTARY CON-
VERTER—In a 500-kw, three-
phase rotary converter, 500
volts direct-current, what
would cause excessive pitting
and burning on the negative
set of brushes?   The machine
carries an average street rail-
way load of about 350 kw.
There is no excessive sparking
or noise.   Would the neutral
point of a rotary converter
change an appreciable amount
with varying loads??   S. B. T.

There   are   numerous   possible
causes of trouble and a cause such
as the present one would be apt to
require the attention of an expert
to determine the source of trouble.
There may be several reasons for
this trouble; for example, brushes
not exactly on average neutral, flat
bars, commutator not in first-class
shape, high mica, other than unity
power - factor, etc. Provided the
power-factor is maintained at unity
the neutral point will not shift.
Over-excitation, for example, will
result in increased armature reaction
which will cause a field distortion

which will in turn result in shifting of the neutral point.   J. B. W.

289—Parallel Operation of Electro-Magnets — Is there any known way by which a number of small magnets (*e. g.*, 20), may be controlled at a distance by a single two-wire circuit, giving selective control of the individual magnets as, for example, by using a different kind of winding for each piece of apparatus and currents of different frequencies?   H. R. K.

At a meeting of the Pittsburg branch of the A. I. E. E., about four years ago, a paper was presented on the subject of "Harmonic Ringing for Four-party Lines with Single Metallic Return Circuit." This paper was a description of a system developed by a telephone manufacturing company and the principle involved was, briefly, that of using four sources of power for the ringing circuit, of four respective frequencies; selective ringing being obtained by the use of ringing magnets at the subscribers' 'phones, so constructed that each of the four instruments would have a definite normal frequency of vibration and thus respond to a given frequency of current. Theoretically, this might be carried out indefinitely, but practically, there are decided limitations, as it is not very easy to obtain the required refinement of tuning. It is possible, however, that such a system as that required could be devised, working on this principle or one analogous thereto, using various frequencies of current. It is not so difficult to make a given magnet operate; the difficulty is to obtain entirely selective operation, *i. e.*, to prevent the remaining magnets of the set from operating.   H. M. S.

290—Difficulty With Starting Squirrel-Cage Induction Motor—A 75-hp., 3 000-volt, 10-pole, 60-cycle, three-phase, squirrel-cage type of induction motor, started by means of an auto-transformer starter, will not come up to speed when the switch is thrown, but runs very slow and at the same time makes a

peculiar shrill noise. If, while running in this way it is speeded up by pulling on the belt, it will then pull into step and take its load without difficulty. After making various tests we have concluded that the trouble is caused by faulty proportioning of the rotor and stator slots which are 89 and 90 respectively. Is it possible that this is the cause of the trouble and if so, what is the explanation?   M. C. H.

The trouble may be due to a combination of conditions among which the ratio of the primary to the secondary teeth may have some relation. If it is possible to procure somewhat higher starting voltage from the auto-starter the motor may be made to develop sufficient starting torque to overcome the locking at the speed noted. The starting transformer probably has a number of taps brought out at different points on the winding, from which various voltages from about 50 percent to 100 percent of line voltage may be obtained. If this does not overcome the difficulty it may be possible to to relieve conditions by substituting end rings of higher resistance or, if the cross-section of the present rings will allow, by increasing their resistance by making a saw cut between each bar. If this is done, care should be taken to leave sufficient cross-section to withstand the mechanical stresses at full speed, and the cuts should be made of uniform depth. It is also advisable to make the cuts in one ring only at first, and then if the trouble is not entirely overcome, to slot the other ring. It is better to procure the exact results desired by more than one cutting than to reduce the cross-section more than is necessary. The noise produced is probably due to vibration set up by an unbalanced magnetic pull or a vibration of loose iron on the secondary.   M. W. B.

291—Rewinding Auto-Starter—A three-phase motor starter consisting of three coils wound on a common core which was formerly used in connection with a 2 200-volt, 60-cycle, three-phase synchronous mo-

tor by connecting through a three-pole, d o u b l e - t h r o w switch, is to be reconstructed to adapt it to the motor rewound for 550 volts, three-phase. Will rewinding the above coils with ¼ the number of turns of four times the cross-section produce the same results at 550 volts as the present winding does at 2 200 volts? N. M. L. P.

With four times the cross-section and one-fourth the number of turns at one-fourth the former voltage, four times the former current will flow. There will be the same number of volts per turn. The reactance volts will be one-fourth the former value; hence, the percentage reactance volts will remain the same. Therefore, the total capacity will remain the same and the starter should operate satisfactorily on the lower voltage. This is just the reverse of the case considered in No. 173 in the JOURNAL for November, 1908. A. P.B.

292—REVERSAL OF POLYPHASE WATTMETER ON TWO-PHASE CIRCUITS—At what power-factor will a polyphase wattmeter reverse on one element when operating, first, on a two-phase—three-wire circuit; second, on a two-phase—four-wire circuit; third, on a four-phase—four-wire circuit? H. C. H.

A polyphase wattmeter connected in any two-phase circuit will not reverse at any power-factor unless power actually reverses in the circuit. If two single-phase meters are used for measuring power in a two-phase circuit feeding a motor, it is possible for one meter to reverse if there is any unbalance of voltage between the two windings of the motor or between the voltages of the two phases. This reversal is not caused, however, by low power-factor, but by an actual reversal of power in one phase, the motor being driven as a generator by the current in the second phase. A. W. C.

293—SERIES TRANSFORMERS—EFFECT OF MAGNETIC LEAKAGE—Will the magnetic leakage between the primary and secondary coils of a series transformer affect the readings of an ammeter connected to the sec-

ondary circuit? A series transformer built for a large bus-bar was used on a bus-bar much smaller than that for which the transformer was apparently designed. Would the magnetic leakage be great enough to affect the readings of the meter, or would the meter have to be recalibrated? B. L.

Increase in the magnetic leakage between the primary and secondary of a series transformer causes an increase in the magnetizing current required, which in turn affects the ratio of transformation and causes a phase displacement between the primary and secondary currents. The error due to phase displacement is shown only in wattmeters and not in ammeters. In the bus-bar series transformer referred to, if well designed, any additional magnetic leakage occasioned by the change in size of bus-bar would not change the ratio of transformation sufficiently to be noticeable on any commercial switchboard ammeter. This is due to the fact that the flux density or induction in a series transformer is very small, being about one-tenth or one-twentieth, or less, of that in a lighting or power transformer. As a result the magnetic leakage is very small. It is common practice in connection with bus-bar series transformers to use one size of core for several sizes of bus-bars. To reduce the leakage to a minimum it would be well to locate the small bus-bar centrally in the transformer opening. Refer also to No. 280 in the JOURNAL for June, 1909. A. D. F.

294—SPECIFIC HEAT OF PORTLAND CEMENT—What is the specific heat of Portland cement in the pulverized form just before going into the kilns? D. W. S.

The process of manufacture of Portland cement is purely mechanical up to the point where the ground mixture of the constituent raw materials is charged into the kiln with the fuel that supplies the necessary heat for the reaction. Strictly speaking, then, it is a question of the specific heat of the raw material rather than that of "Portland cement" and, as the composition of the raw mate·

rial varies according to the process of manufacture (clay and stone, or slag and stone, etc.), it would be almost impossible to give the specific heat without trial. Mr. R. K. Meade in his book on "Portland Cement," gives the specific heat of cement clinker (the product after treatment in the rotary kiln) as 0.246. That the specific heat of the finished product (which is simply the clinker ground and pulverized) is low would be inferred from the fact that cement is a good heat insulator, as brought out in a paper on "Cement Insulation for Cold Storage" presented before the National Association of Cement Users, at the meeting of January 14, 1909, at Cleveland, O. (R. L. Humphrey, secretary, 1001 Harrison Building, Philadelphia, Pa. See also papers by Ira H. Woolson, on "The Effect of Heat on Concrete," Trans. Am. Soc. for Testing Mat'ls, Vol. V., p. 335; Vol. VI., p. 433, and Vol. VII., p. 404. The specific heat of a given kind of cement or mixture of raw material could probably be determined quite accurately as follows: Provide a given quantity of neutral liquid (*i. e.*, which will not react chemically with the material), for example, one or two pounds of oil, the specific heat of which is known, placing it in a vessel of low heat conducting properties and of as light weight as possible; take an equal weight of cement and submerge therein, first allowing the temperature of the oil to become equal to or somewhat below that of the room in which the determination is made; heat the cement to a definite temperature above that of the room; take temperature of each material and of the room by thermometer just before submerging, and temperature of oil after submerging. Then the specific heat of the cement will bear a ratio to that of the oil equivalent to the ratio of the rise in temperature of the oil to the difference in temperature between the cement and the oil immediately before submerging. This method of determination of specific heat is given more in detail in the various engineering handbooks. It may be that this question and the next (No. 295) were asked because of difficulty experienced in connection with the treatment of the raw material in the rotary. If the reaction at this point does not take place properly,

it may be found possible to get satisfactory results by using more fuel, not depending upon the heat of the reaction to assist in obtaining the required temperature. If the temperature of burning is too high or too low the product will suffer in quality. The specific gravity of a properly burned cement is known to have certain definite limits, as explained by Mr. W. P. Taylor in "Practical Cement Testing."   E. P. and T. D. L.

295—EVOLUTION OF HEAT IN MANUFACTURE OF CEMENT—Do the reactions set up during the process of fusing cement clinker give off or absorb heat, and how much?   D. W. S.

Heat generated in the kiln is due to the heat derived from the fuel and that developed as the result of the chemical combination of the ingredients forming the clinker. The results of an investigation by Prof. Richards are as follows:

HEAT GENERATED	CALORIES
1-Theoretrical heating power of fuel.......................................	790 000
2-Heat of Combination................	142 819
Total	932 819

DISTRIBUTION OF HEAT	CALORIES	% OF WHOLE
1-Heat in hot clinker	100 050	10.7
2-Heat in chimney gases		
(a) In excess of air admitted	336 000	36.
(b) In the necessary products	340 000	36.1
3-Heat in flue dust..	2 112	0.2
4-Loss in imperfect combustion......................	12 248	1.3
5-Evaporation of water of charge	1 446	0.2
6-Expulsion of carbon dioxide from carbonates.'	21 628	2.3
7-Loss by radiation and conduction	119 335	12.8
Total	932 819	

(Note: lines (a) and (b) grouped with brace showing 72.1)

From this it is seen that the heat due to the combination of the ingredients is about 15.3 percent of the total heat developed, while the heat required to drive off the water and the carbon dioxide is only 2.5 percent of the total. These tests were made with a 60-foot kiln; the use of 100-foot or 125-foot kilns such as are now being installed would result in slightly different proportions of the above values.

                    C. W. D.

Electrification of Steam Railroads

We are accustomed to hearing the more or less sarcastic comments of steam railwaymen on the conflicting statements of electrical engineers concerning the electrification of steam railroads. Admitting that the electrical engineers have had much to learn in connection with the problem of trunk line electrification, at the same time the steam railways have made a grave error in not sooner appreciating the work which has been done and the methods which have been pursued by electric railways in developing and handling local passenger and freight service. This mistake of the steam railways has resulted in the loss of a large part of their local business in the populous districts; and hundreds, even thousands, of miles of their lines are paralleled by electric railways that would never have been built had the steam railway people properly understood the problem. The article by Mr. Darlington, in this issue of the JOURNAL, is one of the best analyses of the problem that has yet been presented. It goes straight to the root of the matter and presents facts which are incontrovertible; for the statements that are made are not simply theoretical statements, but represent the results of years of experience. The electric railway is now in a better position than ever before. There are available the results of experience in handling by electricity all classes of service from the lightest trolley car to the heaviest freight and passenger trains.

Electric motors were first used on street cars, but soon developed a new field, viz., the suburban and interurban service, which neither the horse car on the one hand, nor the steam train on the other, could reach. The interurban electric road has grown until it far surpasses in efficiency, convenience and economy the interurban service of the steam railway.

Why, therefore, is not the introduction of electric power and electric railway methods into the suburban and interurban service of the steam railway a common sense and logical move? It is the field in which the electric motor has had its greatest triumph, not

simply in handling existing traffic, but in the building up of new traffic; it is the field which the steam railroads are serving with the least satisfaction to the public and the least profit to themselves.

This is the question which Mr. Darlington considers. He gives an excellent presentation of the subject from an economic standpoint, the treatment being comprehensive, while the facts presented are concrete and definite. It is an article of unusual value and should be read by all interested in the country's transportation facilities.   N. W. STORER

College Graduates in the Shop

All who are in any way interested in the development of the graduates of our technical schools will read with great interest the virile and masterful talk on this subject by Mr. Frederick W. Taylor, published in this issue of the JOURNAL. To the technical graduate himself this straightforward and clear statement of his experience with college men by a man of such wide and varied experience and so well known in technical and executive work, is of the keenest interest and, if read thoughtfully, cannot fail to be of great value.

The importance of the actual contact with the workman—the man who earns his living by the skill of his hands—so well brought out in Mr. Taylor's address, cannot be too strongly emphasized. The average college graduate has an undue and exaggerated idea of the value of a mind well stocked with book learning to solve the world's problems. A short time in the shop where manual work is done well and quickly by those who have had none of his valued mental training should cause him to realize that the preparation he has received is at least very incomplete. A little further experience shows him that the quality of mind possessed by many of the shopmen is in no way inferior to his own, bringing a realization that mental training can be had outside of the classroom.

The value of the discipline and training given by doing, day after day, laborious and uninteresting tasks, is well brought out by Mr. Taylor, and should be thoroughly learned by every young man ambitious to succeed. Remember it is not only necessary to do the tasks to attain success, each must be well and thoroughly done. No shirking, no "good enough," but perfect, complete, absolutely to the mark in each piece of work, is the aim that will bring success and require no special genius or unusual attainments.

Those responsible for the success of business undertakings are not seeking for their lieutenants some genius or man of dazzling intellectual qualifications; they are looking for *doers,* men with judgment, experience and training, which can be secured only by discipline in the hard school of everyday work. A technical education should and will help a boy, but it must be understood to be only a help. Work and training bring success.　　　　E. M. HERR

The Liquefaction of Gases

It has been said that we are entering upon an era of specialization; and, it may well be added, that it is one from which there can be no turning back so long as civilization continues to advance. The various arts and sciences have already developed to such an extent as to preclude the possibility of any finite mind grasping more than a part of the theory and practice of any one of them. Almost every addition to the world's knowledge now opens up hitherto unsuspected paths, oftentimes involving either a discarding or a rearranging of prevailing ideas and methods. As a result the apparently simple questions of the past are becoming the complex problems of the present, while the atoms and the elements of yesterday form the molecules and the compounds of to-day. The gradual development of specialists along each of the many different branches of the arts and sciences is, therefore, but a natural sequel of existing conditions. In no direction has progress been more marked, especially during recent years, than in chemistry and one of the most signal feats has been the liquefaction of gases. Less than a score of years elapsed between the laboratory experiments of Cailletet and Dewar and the more practical demonstrations of von Linde, the work of the last mentioned resulting in the production, on a commercial scale, of oxygen and nitrogen from liquid air and creating in consequence a further field for specialization. The importance to the engineering industries of this accomplishment can hardly be over-estimated as the ability to obtain these gases in large quantities at a low cost will in due time revolutionize many methods of manufacture.

Oxygen, although not a combustible gas, is required to support combustion; but, owing to its high cost, hitherto it has been largely necessary to use air instead. As the latter, however, is made up of 79 parts of inert nitrogen and 21 parts of oxygen by volume, the tremendous waste of heat energy taking place in all operations in-

volving combustion as well as the saving to be effected by the substitution of oxygen for air in such operations, will at once be apparent. Likewise since nitrogen forms such an essential element in plant life, one of its largest fields of usefulness in the near future will be in the production of fertilizing compounds.

The article on "Autogenous Welding" in the August issue of the JOURNAL contains descriptions of several methods of obtaining oxygen, but its manufacture from liquid air was not included. The JOURNAL is fortunate in being able to present in this issue an article on "The Liquefaction of Gases and the Commercial Production of Oxygen" from liquid air by Mr. Cecil Lightfoot who has made the subject a specialty and who is well qualified to speak on it not only from the scientific, but also from the practical standpoint.

C. B. AUEL

Repairing Transmission Lines

The article by Messrs. Jenks and Acker, appearing in this issue, contains some valuable and interesting data upon a live subject. It is always a pleasure to read articles presented by such experienced and practical engineers, as they belong to that class of busy men who can seldom be induced to write for the technical press. In the operation of most high tension systems there are times when it is absolutely necessary either to make temporary repairs upon a live line, or else shut down the service. In cases of this kind much credit is due to those who have devised any means by which the hazard to human life is reduced.

There is another point of view, however, which will sooner or later claim more attention from the management of large corporations and the general public, namely, how far can such corporations go in risking the lives of employees in order to save the expenditure of capital necessary to insure the maximum degree of safety to the workmen? If the article is to be interpreted as intending to prove that it is comparatively safe to make such repairs, and thereby confirm the owners of large transmission systems in a policy of jeopardizing the lives of their employees rather than save lives by a larger investment, it sets a dangerous precedent.

It is often interesting to compare ideas and practice in different parts of our country. For instance, in the West large cor-

porations, such as the Helena Power Transmission Company, find it a paying investment to put up a duplicate set of pole lines, each with its own set of transmission wires, to insure uninterrupted service, even though such lines are very expensive and more than a hundred miles long. All but emergency repairs can then be made by shutting down the damaged line, leaving the other in service.

Statistics will undoubtedly show that the extremely high pressures used in the West really result in a smaller life hazard than pressures of 25 000 volts and lower. One reason for this is that at higher voltage, when a person comes in contact with a live line he is thrown violently away from the conductor before a good contact is made, and is more liable to be knocked from a pole than to be electrocuted. Nevertheless, there are many corporations operating systems of lower potential which are much shorter and far less expensive than the lines in the West, which are depending upon single sets of transmission lines for an uninterrupted service, expecting to hazard men's lives every time line troubles show up. The argument in favor is that men can readily be found to undertake the work at their own risk, for fairly high wages, and what is the use of more expenditure? That the work is dangerous is proven by the necessity for the Narragansett resuscitating outfits.

We know that a lineman is one of the most reckless of mortals and many of them seem to delight in exihibits of bravery and foolhardiness. By some final act of carelessness many of them pay their reckoning. It does not seem humane, however, to provide such legitimate and easy means of suicide. By all means let us advocate duplicate transmission lines, if the service must be uninterrupted, whenever it is necessary in the interest of humanity—and especially on account of the wives and children of the linemen.

<div align="right">BERTRAND P. ROWE</div>

ELECTRIC POWER ON STEAM RAILROADS*

F. DARLINGTON

ELECTRICITY is used on railroads under two conditions:—
Where it is necessary for cleanliness, comfort and safety,
largely irrespective of the economy of its use; and where
it is used for its economical advantages.

It is used for convenience and cleanliness in tunnels and on
city terminals of a few large railways. Where it has supplanted
steam in such cases, it has demonstrated its economy compared
with steam on an operating basis, but in some instances ques-
tions of economy are still open when the fixed charges on the
electrical installations are considered. It is safe to say, however,
that no large electrical equipment has been installed where steam
engines were formerly operated in which electricity has not ac-
complished results that could not have been secured by steam.

The use of electricity where it has been applied to railroads
for purely economical reasons is confined mainly to interurban
trolley roads and to city street car lines. City street car lines
are omitted from consideration in this discussion, except as city
street cars affect terminal conditions in large cities, since they
are only secondarily involved in the more general problems of
transportation.

In addition to its present extensive use for city railroad
terminals and railroad tracks in tunnels, there are a few instances
where electric motive power has been substituted for steam for
the purpose of increasing earnings and securing greater comfort
and convenience. Instances of this are the partial change to
electric power on the West Jersey & Sea Shore Railroad from
Camden to Atlantic City, on the Rochester division of the Erie
Railroad from Rochester to Mount Morris, and on the steam
railways from Baltimore to Annapolis, and in some other sec-
tions, and these substitutions have all been highly successful.

The introduction of electric power made interurban roads possible and led to their extensive development for local traffic between cities and along populous routes. Steam railroads have not availed themselves of electric motive power, and hence fail to supply the needs of transportation that are being met by trolley roads.

TWO CLASSES OF ELECTRIC INTERURBAN ROADS

An examination shows that practically there are two classes of interurban roads—the roads of the New England States and New York State and Pennsylvania, and the roads of the Middle Western States. The distinction, and it will become important in the future, lies primarily in the location of the tracks, and in the grades and curves. The trolley roads in the Eastern States are built mainly in hilly countries, on highways and streets. Their grades are usually high and cannot well be reduced, since it is not often feasible to make heavy cuts and fills on highways, and the curves are sharp on account of the turns on highways and streets. In the thickly settled counties of the Eastern States it is difficult and expensive to obtain private right of way for trolley roads, and consequently their tracks are generally bound to follow highways.

In the Middle West electric roads are generally built on private right of way, excepting for short distances where they pass through cities and villages. They are on low grades and their roadbeds, bridges, etc., are built to steam railroad standards. For terminals, trolley roads use mostly the city streets, with a few instances in some of the Western cities of central buildings for exchange of passengers and packages. For the business that is done by trolley roads, stops on city street corners are vastly more convenient than railroad station stops.

The practical difference between trolley roads and steam roads in the Middle West lies almost wholly in the kind of city terminals they have, the motive power they employ and the kind of business to which they cater. Up to the present time trolley roads have confined their attention almost wholly to passenger business, but Western trolley roads are physically suitable for doing much local freight work; their conditions justify it and they will enter the general field of steam railroad operations more and more, especially in level countries.

EXTENT AND ECONOMY OF INTERURBAN ROADS IN THE MIDDLE WEST

The most trustworthy judgment of the economy of using electric power on railroads can be had from results that these Middle West interurban roads are accomplishing. In the three Middle Western States, Ohio, Indiana and Illinois, where the total mileage of electric interurban railroads was about 5 000 miles in 1907, the combined steam railroad mileage was about 28 576 miles, or the trolley road mileage was 17.6 percent of the mileage of the steam roads. About 85 to 90 percent of the trolley road mileage is in direct competition with steam railroads between cities, and about 75 to 80 percent of the trolley road mileage directly parallels the tracks of the steam railroads, competing for local as well as interurban traffic. The gross earnings of $26 000 000 per year total for the interurban trolley roads in these three States are about $5 200 per mile of trolley road per year average. This business is derived almost wholly from carrying passengers, a very small portion of it being from freight, mails and express, and miscellaneous sources. The annual gross earnings of the steam railroads in the same States are probably about $430 000 000, of which about $97 000 000 is derived from passenger and mail and express business and the balance from freight and miscellaneous business. From this it will be seen that though the gross earnings of the trolley roads in these three States are only about six percent of the gross earnings of the steam railroads, they are about 27 percent of the gross passenger, mail and express earnings of those railroads.

TRAFFIC CONTROLLED BY ELECTRIC RAILROADS

Electric lines form an essential link between main line railroads and their customers, so the business of electric lines is important in the general scheme of transportation in a larger proportion than the ratio of its volume to the total business done. The traffic of electric roads originates upon their own lines and to a great extent is created by them. Trolley roads are now serving as feeders to collect traffic, and as their importance grows they carry this over longer and longer distances and get a more and more complete control of transportation from its origin to its destination. The value of feeders and branch lines in large railway systems has always been recognized, and many branch lines that are unprofiable in themselves have been built and operated for the business that they create and bring in to main

lines. This necessitates local service, and this is the field in which interurban electric roads are now working and in which electricity has shown one of its chief advantages over steam.

If fifteen years ago the officers of the large transportation systems of the United States had been told that electric railroads would enter the territory covered by their tracks, would closely parallel them and usurp their local business, they would have considered the fulfilment of the prediction unlikely, to say the least. If they had then foreseen the present situation, it would have been considered a serious menace to their operations, as indeed it has become, and the menace will increase if conditions are not wisely met. To meet the situation it will be necessary for the steam railroads to employ electric power for those kinds of transportation work in which its superiority over steam has been demonstrated by trolley road developments. Wherever there is a considerable local traffic to be handled, trolley roads have proven the superior economy of electric service; and in such sections steam roads must eventually adopt electricity for conducting local traffic.

ELECTRIC RAILROADS GET THE BEST TRAFFIC AND LEAVE THE POOR

There is one element in the interurban electric road business to which attention should be given, that these roads are not competing with the steam railroads for the local business in the sparsely settled and unprofitable parts of the country, but in the richest and best and those most productive of receipts from local transportation. The 5 000 miles of electric road in Ohio, Indiana and Illinois take their trade from the heart of the local passenger business of the steam railroads; but they do not depend for their profit strictly or mainly on the traffic they take away from the steam roads. The accommodations that trolley roads offer build up traffic both by inducing travel from existing sources and by developing the territory along their lines and attracting additional population and new enterprises.

In the case of the trolley roads of the Middle West there are no set conditions that will limit their extension and their entrance into new lines of business, including longer hauls, the haulage of freight, etc.; and as long as they possess the power to originate and create new business and at the same time take established local business from steam railroads, they hold the key to the

non-competitive trade, and when their extensions carry their
termini into competitive points they will be in position to offer
the business that goes beyond their lines to the lowest bidder.

COST OF FREQUENT TRAIN SERVICE

The economical conditions determining the best frequency of
service are entirely different on electric roads and on steam roads.
The former operate single cars with apparatus and equipment
that is especially designed for quick and cheap single-unit opera-
tion.   A comparison of the operating expenses and earnings of
nineteen interurban electric roads in Illinois shows the average
operating expense on these electric systems to be 15.8 cents per
car-mile.   This average cost is divided about as follows:—

Electric power	3.73 cents
Operation of cars	5.40 "
Maintenance of cars and equipment	1.30 "
Maintenance of roadbed, overhead lines and buildings	1.70 "
General expenses	3.67 "
Total as above	15.80 cents

Steam railroads operating trains are put to a much higher
cost per train-mile.   Each steam train consists of a locomotive
with an engineer and fireman, and coaches with a conductor and
brakeman, against a crew of a motorman and conductor on a
single electric car.   The rates of wages on the steam trains are
higher than on electric cars, and steam locomotives are more
costly to maintain than electric car apparatus; in fact, the mo-
tive power cost alone of steam railroad service per train-mile
generally far exceeds the total operating cost per car-mile for
electric roads.

The cost of operating light local steam railroad trains, with-
out including the maintenance of the roadbed and the wages of
station attendants and the general expenses of the railroad,
usually comes to 40 to 60 cents or more per train-mile.   The
nineteen interurban electric railroads in the State of Illinois,
mentioned above, make gross earnings per car-mile of about 29.5
cents, or say roughly their gross earnings are only about two-
thirds of the actual cost per mile of operating light steam trains.

It may seem at first sight that it is illogical to compare the
cost of operating a single electric car with the cost of operating
a steam railroad train, but for practical results this is the way to
make the comparison for local interurban business.   Trolley roads

generally charge between one and one-half and two cents per passenger-mile, and their cars have a seating capacity of 45 to 60 passengers. Their earnings for a general comparison may be taken at about 27 cents per car-mile and their operating expenses at 16 cents per car-mile.

RELATIVE EARNING CAPACITY OF SINGLE CARS AND TRAINS OF CARS

With fares on trolley cars averaging one and one-half to two cents per passenger-mile, the average occupancy of a car to pay 27 cents is only in the neighborhood of 15 or 16 passengers. A rather complicated question arises here as to the relative earning value of a steam railroad train with two or three coaches and a trolley car with a seating capacity of 45 to 60; but in places where the trolley road earnings are made from an average occupancy of less than half the seating capacity of the cars and where frequent service is necessary in making these earnings, it would obviously be unprofitable to haul trains of three or four cars to carry the passengers. If there is sufficient travel to overload the ordinary interurban car, it will usually be profitable to increase the frequency of the schedule, since an increase in schedule will stimulate further travel and can be made at an operating cost per car lower in proportion than the 16 cents assumed as an average figure, since that includes maintenance of track, maintenance of trolley, general expenses and other items of cost that do not increase in direct proportion to the number of cars in operation.

The gross earnings per mile of track per year of ordinarily successful trolley roads lies between the limits of $4 000 to $7 000. The operating expenses average about 60 percent of the gross earnings, which deducted from $4 000 to $7 000 a year gross earnings leaves a net earning per mile of track of $1 600 to $2 800. This is a fair statement of the showing of average successful interurban roads.

NECESSARY MINIMUM EARNINGS FOR PROFITABLE TROLLEY DEVELOPMENT

Interurban trolley roads producing average net earnings per year of about $1 600 to $2 800 per mile of railroad would return about 6.4 to 11.2 percent on an investment of $25 000 per mile, or about 5.3 to 9.3 percent on an investment of $30 000 per mile. Where conditions are favorable, interurban trolley roads have been built and equipped (especially in the Western States where

there are not many bad hills or costly bridges) for $25 000 to $30 000 per mile of road, averaged approximately as in Table I.

From these figures may be determined very roughly the lowest returns under which interurban electric roads doing local business can be made profitable. When analyzed they show that the return on their cost must be small where the gross earnings

TABLE I—COST OF ELECTRIC RAILWAYS

IN THE MIDDLE WESTERN STATES UNDER CONDITIONS FAVORABLE FOR CHEAP CONSTRUCTION

	For Roadbed.	Cost per mile
Grades and bridges		.$ 5 000
Ballast		3 000
Ties		1 200
Surfacing		500
Steel		4 000
Right of way (variable)		1 000
Add for general expenses, say		1 500
Total cost of roadbed per mile of track		.$16 200

For Cars and Electrical Equipment, Power Plant, Substations and Feeder.

		Cost per mile of Track
Cars and equipments, $1 000 to $2 500; about		.$ 1 200
Power plant, $1 200 to $2 400; about		2 200
Transmission lines, transformer stations or substations, feeder cables, etc., $1 500 to $4 000; about		3 000
Trolley, etc.; about		1 600
Add for general expense engineering and interest per mile of track		1 000
Total for power plant, cars, transmission lines, etc., per mile; about		9 000
Total cost of trolley road construction, power plant, and equipment per mile of track; about		25 000

per year are less than $3 000 or $4 000 per mile of track, or the net earnings less than $1 200 to $1 600 per mile, and independent trolley road investments will not be attractive with smaller earnings except under exceptionally favorable circumstances. Experience has taught that trolley roads parallel to steam railroads generally realize these earnings wherever the gross earnings from local business of the steam roads prior to the commencement of operation by the trolley roads were from $1 000 to $2 000 per mile per year. The trolley roads, by reason of their superior convenience, take from the steam railroads and create enough business to make up the necessary total. Their profitable extension

ends in the countries where the earnings from local service will not pay a profit on an investment of about $25 000 per mile of road.

STEAM RAILROADS CAN MAKE LARGE PROFITS

The adoption of electric motive power on steam railroads, and the maintenance of a convenient and frequent service where there is a considerable local business which can be handled advantageously with electric cars, will result in a handsome increase in their earnings. The opportunity of steam railroads for this kind of work is in many places much better than that of independent trolley lines. In the first place, steam railroads have existing right of way, bridges, stations and station attendants, all of which are indispensable to them in connection with their through business which, up to the present time, has been very little encroached upon by electric roads. Furthermore, steam railroads as a rule have far better facilties for raising money for development purposes than electric roads. The latter usually sell five percent bonds to raise the money for their construction work and receive from these bonds about 85 percent, more or less, making the fixed charge on their cash investment about six percent. They have all the expense of independent organization and management, both for construction and operation, to which are generally added large promotion charges. Steam roads, with their established organizations, with the lower interest cost for the money that they spend, and with their right of way already owned, can build and equip electric lines to the best advantage. Furthermore, steam railroads establishing an electric service on their lines could utilize their present tracks to a certain extent for electric cars, as standard electric railroad apparatus, which in no way interferes with the operation of steam trains over the same tracks, is regularly manufactured. An electric schedule on a steam railroad will permit the entire discontinuance of steam trains for local passenger and local freight and express service. Experience has demonstrated that local freight can be handled more cheaply with electric motive power than by steam. A properly equipped baggage, freight, and express car, with standard couplers and with motors properly adapted for high tractive effort at low speeds, is suitable for hauling a considerable number of freight cars as trailers.

In some recent calculations for a steam railroad where the

cost of handling the local freight business is well known, the cost of handling the local freight by steam is 54 cents per train-mile. The same work could be done with a motor car using electric power costing one cent per kilowatt-hour for about 22 cents per train-mile, which would be a saving in local freight operation of more than one-half.

A large railroad having a terminal in Chicago with one of the heaviest suburban services in America, and with an exceedingly large freight terminal business in Chicago, is making a careful study of the Chicago end of its line. It is examining with the utmost care the commercial side, as well as the engineering, of the electrification problem and is studying the results it could get in the different kinds of work to be done. It has not announced its conclusion resulting from this study, but certain features of the proposed work are apparent, viz: the local or suburban passenger business can be handled rapidly and economically with electric equipment; the through business, both passenger and freight, can be handled with economy and certainty by electric power. The through freight business, because the trains are heavier and slower than the through passenger trains, will realize smaller economical advantage from electrification than the passenger business.

STEAM RAILROADS CAN BEST SERVE CITIES WITH INTERURBAN CARS

Steam railroads, to get the full benefit of electric operation, ought to secure the same terminal convenience and the consequent advantages that interurban electric roads have. At first sight this appears difficult, as popular prejudice is against giving steam railroads the same privileges as electric roads for moving cars through cities and villages, even if the steam railroads agree to use electric power on the streets. This discrimination is purely a question of public prejudice and should be overcome, since steam railroads having tracks on private right of way reaching generally well within city limits require relatively short distances on city streets to reach the populous centres. The entrance of trolley roads to cities almost always necessitates a long course over several blocks or several miles of city streets, which means an annoying and dangerous occupancy of the streets and relatively long stretches of slow-speed movement for interurban trolley cars. Steam railroads, on the other hand, having terminals reasonably near to the city centers, could (if they were

granted the privilege) run electric cars from the nearest point on their steam railroad tracks, directly to the populous centers, occupying the streets only for the distance from their tracks to the populous centers and returning their cars to their own line by the same route or by a short loop. In this way the mileage of city streets encumbered by interurban electric service if furnished by steam railroads would be much less than that ordinarily taken by independent trolley roads; and the distance being shorter, the incentive would be less to run at high speed through the city streets and the danger would therefore be reduced.

There can be no doubt of the facts already brought out—that electric roads are particularly suited to gather up and concentrate and take away from steam railroads their local business. Electric roads, with their advantages for profitable extension and development on the low grade and private right of way in the Western States, may eventually build up a system of electric lines parallel to the steam railroad in their best territory and equip themselves to do all kinds of work done by the steam roads and to excel them in handling local business.

THE ECONOMICAL PLACE OF ELECTRIC MOTIVE POWER

It is clearly the duty of the steam roads to realize this situation and meet it in some practical and reasonable manner. Whatever else may be necessary in the premises, one thing is clear—that there are many opportunities for the steam railroads profitably to make themselves combined electric and steam lines by utilizing the advantages of electric power. The natural and economic method would be to install on the steam railroads electric service at the most advantageous points, which are also the most vulnerable to trolley competition; to make the new equipment part of a plan of general railroad improvement, and to extend the electrified lines as economy and profit dictate.

THE LIQUEFACTION OF GASES AND COMMERCIAL PRODUCTION OF OXYGEN

MACHINES FOR THE PRODUCTION OF THE LOWEST TEMPERATURES FOR THE LIQUEFACTION OF GASES AND THE CHEMICAL SEPARATION OF GASEOUS MIXTURES

CECIL LIGHTFOOT*

THE researches of Cailletet, Dewar, Olszewski and von Linde, have clearly determined the conditions necessary to bring about the liquefaction, by mechanical means, of gases, including also those gases until recently termed "permanent." It is now a well-established fact that in every case the temperature of the gas must be reduced below a certain point in order that a change in physical state may take place. This point, which is termed the "critcal temperature," is often very low, in the case of atmospheric air being about 140 degrees below zero Centigrade. The necessary reduction in temperature is effected by the use of apparatus in which the cycle of operation is based on the conversion of energy from one form to another.

The curves shown in Fig. 1 illustrate the properties of different gases. The ordinates represent the temperatures in degrees, C. and the abscissae the specific volume (i. e., the volumes of unit weight) which correspond to those temperatures, on the left in the liquid state, and on the right in the condition of saturated vapor. It should be borne in mind that the characteristic feature of a saturated vapor is that, at constant temperature, any reduction in volume results in the liquefaction of a portion of the vapor. By following any of these curves from left to right, it will be seen that the specific volume increases slightly with rapidly increasing temperatures. Following along from right to left it will be noted that the reverse is the case, (due, of course, to corresponding increase in pressure with increasing temperature) and this reduction in volume becomes gradually less and less until at last, at a certain point, both branches of the curves join. The point at which this union takes place is the critical point of the gas. To it belongs a definite

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critical temperature, a definite critical pressure, and a definite critical volume.

The condition of a gas at any temperature may thus be completely defined by the relative position of a point indicating its temperature and its specific volume in regard to this curve. It may be in any one of four different conditions:—

Specific Volume
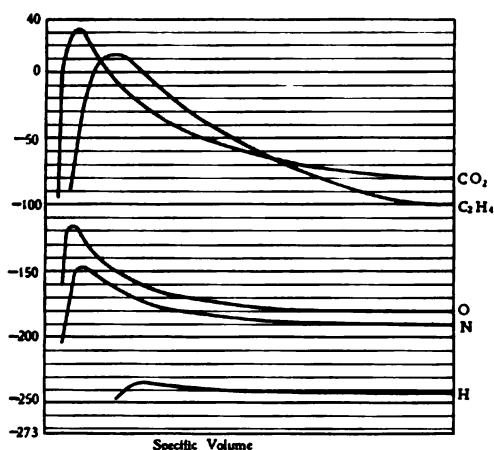
FIG. I

1—If the point lies in the left-hand branch of the curve, the gas is completely liquid.

2—If it lies in the right-hand branch of the curve, the gas is in a state of saturation.

3—If it lies between the two branches, it is partly liquid and partly gaseous.

4—If it lies outside the right-hand branch, the gas is in a superheated condition, and the further this point is removed from the curve, the more nearly does it approximate to the condition in which it obeys the laws for perfect gases.

TABLE I

	Critical Pressure Atmos.	Critical Temperature Degrees C.	Boiling Point Degrees C.	Freezing Point Degrees C.
Water..........	200	365	100	0
Ammonia.......	115	130	—33	—77
Carbonic Acid..	75	31	—80	—56
Ethylene.......	52	10	—102	—169
Oxygen........	51	—119	—182	...
Atmosphere Air	39	—140	—191	...
Nitrogen.......	35	—146	—194	—214
Hydrogen......	20	—234	—243	...

Table I gives the values of the critical temperature of some of the more important gases. It is impossible to bring about liquefaction of atmospheric air, for example, so long as its temperature remains above — 140 degrees C. No amount of pressure

will suffice.   Once, however, the temperature is reduced to — 140 degrees C., no greater pressure than 39 atmospheres is necessary.   If it is not possible to obtain this pressure, then the temperature must be still further reduced to the temperature corresponding to the pressure at disposal.   If it is desired to liquefy the air at atmospheric pressure, it must first be cooled down to a temperature of — 191 degrees C.*

In the perfect gas the intrinsic energy is quite independent of the pressure, so that when a perfect gas expands from a higher to a lower pressure without the performance of external work, as when issuing through an orifice, the temperature of the gas before and after expansion is the same..   Air, for example, is not a perfect gas and such expansion does not take place isothermally for, with increasing pressure, its intrinsic energy decreases; consequently, when air escapes from a higher to a lower pressure its temperature decreases owing to the necessary conversion of a certain number of units of sensible heat into internal work.

MACHINES FOR PRODUCING LIQUID AIR

The action of the Linde machine for air liquefaction is based on the refrigerating effect resulting from the expansion of air from a higher to a lower pressure, and which is due to the performance of internal work.   At ordinary temperatures, this reduction in temperature amounts to about three-tenths degree C. for each atmosphere of difference in pressure.   It is, therefore, too insignificant to produce liquefaction of air at a single expansion since this only takes place below — 140 degrees C. (critical tem-

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*The first successful attempt to liquify a so-called "permanent" gas seems to have been made by Cailletet in 1877, when by the adiabatic expansion of highly compressed oxygen. previously cooled by means of sulphurous acid to—29 degrees C., he obtained this gas in the form of a dense cloud.   He was quickly followed by others who used similar methods, until ultimately Dewar, in 1884, developed his cascade process, employing carbonic acid and ethylene evaporated under vacuum to produce the necessary cooling effect.   This method, however, was only suited for laboratory work and had no direct commercial value.   Subsequent attempts were made by Solvay and others, but they met with no success, the cascade process of Dewar remaining the only practicable method of producing liquid air, until in 1895 Dr. Carl von Linde described his counter-current interchanger to a meeting of scientists in Munich.

perature of air) and at — 191 degrees C. at atmospheric pressure, this being the boiling point of liquid air.*

In the Linde machine the action of any desired number of expansions is accumulated and intensified by causing each preceding expansion to act as a fore-cooler to the air for the following expansion. This is attained by adopting the principle of heat interchange which is, in this case, most efficiently applied by employing concentric tubes placed one inside the other and coiled in spiral form, as shown in Fig. 2. The compressed air flows from top to bottom through the inner tube of the vertical double coil, expands through a valve between the inner and outer tubes from the bottom to the top, transmitting the cooling effect produced by expansion to the compressed air flowing down the inner tube. As a result the temperatures of the air before and after expansion are continuously reduced to the temperature of liquefaction, and part of the expanding air will collect in the liquid state in a vessel situated at the lower end of the heat-interchanger.

As the refrigerative action of the apparatus depends upon the difference of pressure before and after expansion, while the work of compression corresponds to the ratios of these pressures, the advantage of selecting a large difference in pressures, but a small ratio of pressures is apparent. In the machine herein described, the greater part of the cooling effect is produced by the expansion of air at an initial pressure of about 200 atmospheres to a pressure of 20 to 50 atmospheres, so that (according to the size of the machine, the difference of pressure is about 150 to 180 atmospheres, while the value of the ratio varies approximately from four to ten. Only the small quantity of air requisite for the primary charge and its subsequent renewal is introduced into the cycle from the sur-

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*As early as 1853 Thompson and Joule carried out a series of experiments to determine the exact amount of this decrease in temperature and so obtained a basis for calculation. The results of these experiments proved that at a temperature of zero C. for every atmosphere decrease in pressure the loss in temperature was 0.276 degree C., and that owing to the increase of specific heat of the gas with increasing pressure, this cooling effect varies inversely as the square of the absolute temperature at which expansion takes place.
From this was derived the following formula:—

$$T_1 - (p_2 - p_1) \times 0.276 \times \frac{(273)^2}{(T_1)} = T_2.$$

Where, T_1 = Temperature before expansion,
T_2 = Temperature after expansion,
p_2 = Initial pressure in atmospheres,
p_1 = Final pressure in atmospheres.

rounding atmosphere, leaving it again partly as liquid and partly as gas at atmospheric pressure.

The Linde machine for the liquefaction of air consists of the following parts:—

1—The heat-interchanger.

2—The air-compressing plant.

3—The appliances for the preliminary cooling and drying of the compressed air.

1—THE HEAT-INTERCHANGER

As will be seen by reference to Fig. 2, the heat-interchanger consists of a triple coil composed of copper tubes placed one within the other. The cycle for air is performed, as already described, by causing air compressed to 200 atmospheres to flow downward through the innermost coil, at the lower extremity of which it is allowed to expand to an intermediate pressure of 20 to 50 atmospheres. The expanded air is then returned through the annular space between the innermost and middle coils to the top of the interchanger, when it is again compressed up to 200 atmospheres pressure and the cycle is repeated. Immediately behind the first regulating valve A is placed a second valve B through which, when the operation of the machine has been brought to a state of equilibrium, a small quantity of air is allowed to escape at atmospheric pressure, a corresponding amount being introduced into the cycle from the surrounding atmosphere. Part of this air leaves the second regulating valve in the liquid air state and collects in the vessel C; the remaining portion is returned to the atmosphere through the annular space between the middle and outer coils. The liquid air is drawn from the collector by means of the small cock D.

2—THE AIR-COMPRESSING PLANT

In the larger installations the necessary compression of the air is effected by means of a high pressure air pump, which is usually arranged for two-stage compression, working in conjunction with a single cylinder low pressure air pump. The high pressure cylinder F of the former draws the partly expanded air from the heat-interchanger at an intermediate pressure of about 50 atmospheres, and compressing it up to about 200 atmospheres pressure, delivers it to the interchanger again, through the cooler E. The air which is to be added to the cycle as "make-up" is

supplied by the low pressure air pump *H,* which draws it from the atmosphere, compresses it to a pressure of about four atmospheres, and delivers it to the low pressure cylinder (not shown in the figure) of the high pressure air pump, where it is compressed to a pressure of about 50 atmospheres. At this pressure it enters the high pressure cylinder, together with the partly expanded air from the heat-interchanger, as described above.
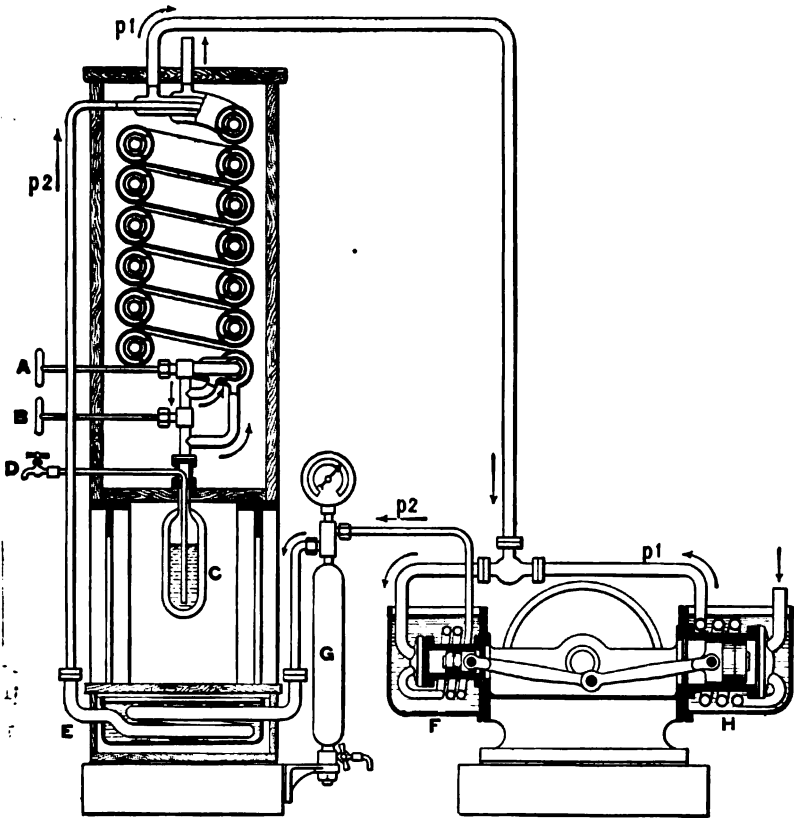
FIG. 2—APPARATUS FOR LIQUEFYING AIR

Regulation of the several pressures is performed with the aid of pressure gauges by means of the regulating valves in the heat-interchanger. Safety valves are provided to prevent the maximum pressures being exceeded.

3—PRELIMINARY COOLING AND DRYING

The duty of air-liquefying plants is considerably augmented

by a preliminary cooling of the compressed air prior to its enter-
ing the heat-interchanger. For this purpose a fore-cooler is pro-
vided, by means of which the compressed air is reduced in tem-
perature to — 12 or — 15 degrees C. by filling the re-
ceptacle provided for the purpose with a suitable freezing mix-
ture, such as ice and salt. With larger installations, the pre-
liminary cooling is brought about by a small belt-driven refriger-
ating machine on the ammonia compression system. The adop-
tion of fore-cooling is advisable in all cases, but especially when
the cost of power is an item of great importance.

Between the compressor and the fore-cooler apparatus, *G,* is
provided for separating water from the compressed air. This ap-

FIG. 3—INTERCHANGER AND RECTIFIER

paratus is provided with a suitable drain cock. Further extrac-
tion of the aqueous vapours from the compressed air in the small-
er installations is effected after the last stage of compression by
means of chloride of calcium.

APPARATUS FOR THE PRODUCTION OF PURE OXYGEN BY THE FRAC-
TIONAL EVAPORATION OF LIQUID AIR

The principle of the Linde apparatus for the production of
oxygen from the atmosphere consists first of all in the complete
liquefaction of the air to be resolved, as has already been de-
scribed. The liquid air thus obtained is then passed through
an inter-changer, Fig. 3, in which it acquires the necessary
latent heat of evaporation by assisting in the liquefaction of a
further supply of air, and is then subjected to a process of rectifi-

cation. This rectification, which is very similar to the process employed in spirit refineries for the separation of alcohol and water, enables oxygen having a purity of 95 percent to be delivered from the apparatus. If the output be reduced by 10 to 20 percent, the quality of the oxygen produced may be brought up to as high a degree of purity as 98 or 99 percent.

The interchange of heat which takes place in the apparatus is so complete that before the by-product nitrogen is returned to the atmosphere so much heat has been removed from the incoming air that it leaves the bottom of the fore-cooler at a temperature considerably below freezing point, and then enters the top of the separator, passing downward through a series of coils, which are so constructed as to be surrounded by both the outgoing cold
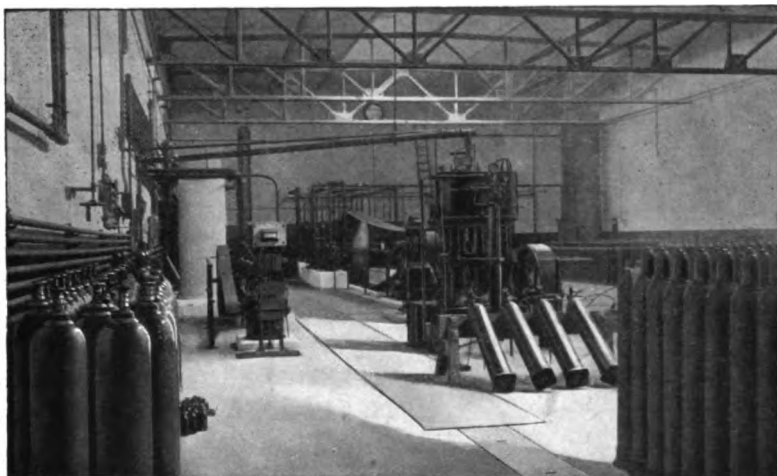
FIG. 4—INTERIOR VIEW OF WORKS FOR MAKING OXYGEN

gases, i. e., both oxygen and nitrogen. The bottom of the separator contains liquid air, or more correctly speaking, liquid oxygen. The compressed air, on its way to the expansion point, is conveyed through this liquid, by which means it is largely condensed. It then passes through the regulating valve, at which point it expands, and it is ultimately discharged into the top of an inner central chamber which forms the rectifying column in which the separation of oxygen and nitrogen is effected, oxygen descending in a liqud state to the bottom of the separator, and nitrogen ascending in a gaseous or vaporous condition to the top.

The nitrogen is allowed to discharge freely into the atmosphere through an extension of the fore-cooler, and the oxygen is allowed to boil off in any desired quantity by the adjustment of an oxygen discharge-valve. Both gases, however, as already stated, on leaving the separator are kept in intimate contact with the coils conveying the incoming air, so that before leaving the apparatus the heat of the incoming air has been mostly transferred to the gases. It will thus be seen that after equilibrium has been attained, the process is practically automatic.

A view of a portion of the main engine room of the Buffalo works of The Linde Air Products Company, where this process is carried on, is shown in Fig. 4. The plant is driven by electric power from Niagara Falls. There are two separators and two fore-coolers, one of each being operated at a time. In this way continuous working is ensured, for when ice, (due to untrapped traces of moisture in the air) has accumulated to such an extent as to cause a blockage in one separator, the other can be put into operation while the first is allowed to thaw. Air is compressed by a four-stage belt-driven compressor. The compression is practically adiabatic, and after each stage the heat of compression is removed by passing the compressed air through a cooler, in which water is circulated. The purification of the air is practically complete, the carbonic acid being eliminated in specially constructed apparatus while the moisture is removed by freezing in a fore-cooler, which is employed partly for this purpose and partly to reduce the temperature of the compressed air before it enters the separator.

WHY MANUFACTURERS DISLIKE COLLEGE GRADUATES*

FREDERICK W. TAYLOR

THE educational question interests me entirely from the view point of the user of engineering graduates and not from that of the profession. It has been my good fortune to have the training of several hundred engineering graduates and, therefore, it must be apparent that, in the criticism which I have to offer regarding the young men, I am not opposed to engineering education as a preparation for life. On the contrary, in all cases where possible, I invariably select an engineering graduate for almost any large position which needs to be filled. I want to make the matter perfectly clear because in the kind of criticism that I propose to present, one is very apt to be led to the conclusion that I am bitterly opposed to the engineer as he is now trained.

As to the value of the young engineers, there ought to be no question in the mind of any impartial investigator as to the enormous value of an engineering education for success in actual, practical life, in commercial life, in manufacturing life, and in engineering life. On the other hand, I think probably you gentlemen are not in very close touch with the general public opinion of the country as regards young engineers.

You are many of you inundated with letters asking for the services of your young graduates, and from these it is perfectly natural to suppose that the country at large wants them very badly. Now I do not think there is a shadow of doubt but that the overwhelming majority of employers of this country want to have nothing to do with them if they can help themselves. That is a fact, and I think it is one that you gentlemen ought to appreciate as

having a great bearing on the educational problem. Mr. Crane, of
Chicago, has very aptly represented this type of men. He stands,
however, almost alone in representing this view, and I have heard
Mr. Crane laughed at, sneered at and held up to ridicule to such an
extent that it appeared to me that Mr. Crane's view of the matter
is hardly even tolerated by the men who are engaged in university
teaching, whereas he is voicing the view of the great majority of
the employers in this country. They say nothing, but they agree
over and over again with Mr. Crane. I want to give one illustra-
tion of this. I was recently in the Middle West at one of the
largest and most successful manufacturing companies in the coun-
try. They had present some thirty of the heads of their depart-
ments; their president, vice presidents, general manager and super-
intendents, and after I had said a few words in regard to the fact
that there were so few college employees in their organization, the
president of the company who was a college man himself, rose and
said, "Well, this is an entirely new experience to us. Here is a
man for whom we have a certain regard, and who has the reputa-
tion of being a practical man, and he tells us we had better use the
college man instead of the commercially trained man." They al-
most all laughed, although there were four college men among
them, and those four were as firmly convinced of the inutility of
the college man as any of them.

I want you to appreciate that that sentiment exists right now,
very largely in this country. I think those who have had the long-
est and largest experience with them want them the most, but I
dare say, they only want them on the average after they have been
out of college for one or two years. They want someone else to
take them first.

There is one exception to this not wanting to employ college
men which is quite prominent. The large electric companies are
employing them on a large scale, but it is my opinion that they are,
to a large extent, exploiting the young men; that the opportunities
which they get in the large electric companies are in no way com-
parable to the opportunities which would be open to the same men
if they went into smaller industries with their greater diversity.

Now that is one side of the question. The other side comes to
me from my personal observation. I think it is also true that nine
out of ten of these young men are dissatisfied for at least one or
two years. They find their employers unappreciative and exacting.

They are not given any kind of opportunities commensurate with their education and what they are able to do. They are asked to do work that mere boys could do. Almost invariably, they want to leave their first employer, and it is only after going to their second or third that they become aware of the fact that the boys that they make light of are the ones who can do things and are the ones favored by the employers, and that the whole or nearly all of the employers of the country are not really unappreciative. Some ten years ago I made up my mind never to employ a college man who had not been out two years at least, if I could help myself. Then he will have learned something about life and what the world is.

Now are those two conditions indispensable? Are they indispensable conditions to the young graduate? Is it necessary that the young graduate should be turned out so that he is unhappy and discontented for a period of two years more or less after he graduates? And is it necessary that the young graduate should go out with such an education that the average employer, who is an honest man, who really believes that he is right, feels that these young men are not what he wants. Is that condition indispensable? I most firmly believe not. I believe that the young graduate can be turned out so as to be useful right from the start, and I believe that there are two particular faults which are responsible for this condition of affairs, both of them remediable.

The first of these is because of the fact that during the four years that these young men are at college, they are under loose discipline, and are allowed a greater freedom than they have ever had before, or will ever have again.

I will cite some illustrations. In most universities and colleges the student is given, every term, a certain number of cuts for which he is held to no responsibility. He can simply absent himself from recitations, from lectures, from duty that belongs in the college course, and no one ever asks what he has done, or where he has gone. If that same young man absents himself once without a reasonable excuse, when he gets into business, he is usually hauled up and asked in the most impertinent manner, why he was away. No cuts in business, no talk about how many cuts a man has. The second or third time that he does cut, he is discharged. Young college men work when they please, and as much as they please, the only restrictions being that they have to pass certain examinations. Their habits are left almost entirely to themselves. When

they begin commercial life those habits are regulated and rigidly prescribed by some one else.

The radical difference of treatment which these young men receive in college, from what they receive afterwards, to my mind, is the lesser of the two reasons for the two fundamental facts that I have described, namely the unhappiness of the young man when he gets out, his failure to fit in his surroundings, and great lack of demand for these young men throughout the country.

The reason for this is that for twenty-two years these young men are allowed to go without even a single look at conditions which they are to face throughout their lives. The work of the student, of the young man, is that of absorbing; he is engaged in the performance of getting things fastened in his mind for himself, for his own use. That is his life for twenty-two years. The moment he gets out he begins directly the opposite. Absorbing ceases and becomes a very minor part of a man's work. He begins giving the few ideas, or the many which he may have gotten, to help some one. He has been served for twenty-two years by some one else, the moment he gets out he begins serving others. Is it any wonder these young men find great difficulty in suddenly changing from the attitude of sponges, or absorbers to that of human beings actively engaged for the benefit of someone else? I think the wonder is that they adjust themselves so quickly to it.

The central idea that the boy gets at college is training, training of the mind, storing the mind full of things. Now I say, without the slightest hesitation, that for success in life, intellectual training comes second or third. Without the slightest question, character comes first; good sense, second, and intellectual training third. The entire emphasis of the college life is on intellectual training. As long as the man commits no offense which sends him to jail, it is very little of the business of the management of those universities what those boys do.

What is the remedy for these two faults? I do not believe there is any panacea for all faults, but I do believe that there is a great palliative possible. I believe that every young student in our colleges, from the student who intends to be a minister, on the one hand, to the mechanical engineer, on the other hand, should leave college at the end of the freshman year and spend at least one year in actual hard work in a shop of some kind. I say shop, because he will be certain to be under careful and constant supervision when working in a shop as a workman, alongside workmen.

I would not send them there with the idea of getting intellectual training. If they do, it is a mere incident. I would send them there mainly for the purpose of giving them a real look at life's work and give it to them early enough so as to affect the last three or four years of their college life. When they start work in a shop, under good rigid discipline, they then begin to get the character training, which is almost entirely lacking at college. They then begin to learn the great lesson of life, that almost nine-tenths of the work that every man has to do is monotonous, tiresome and uninteresting. Then they start to develop the character which enables them to do unpleasant, disagreeable things. This is the greatest training, to my mind, which they get in the shop. They learn that life is made up mainly of serving other people, not that the world is there to teach them something new. I think that almost invariably they start into the shop with the common idea, "Now I am here to learn something, to get something in this shop that is going to be a fine engineering education for me." They fail at once, for there is no great intellectual training in the shop. Many of them cannot stand the monotony and fail to get the real character training that comes from that work.

There is another thing that they learn, which is of enormous importance for these young men, and I think it has more to do with making them earnest and determined than anything else. You could lecture to them and talk to them from now to doomsday, and tell them that the man who goes along the street in greasy overalls, that the man who runs a lathe, is mentally as well equipped as they are and they won't believe it. They may acquiesce mentally, but away back in their brains they say, "Oh, yes, I will believe it, but it is not so." That is their mental attitude.

Young men who work in any first-class establishment find that men who cannot talk grammatically, that men who chew tobacco, slouch along the street with greasy overalls on, who hardly look up, who are scarcely willing to speak to you politely as you go along, are intellectually as clear as they are. That is what the young men learn. I remember very distinctly the perfectly astonishing awakening at the end of six months of my apprenticeship, when I discovered that there were three men in the paintshop, I being the fourth, who were all smarter than I was. Now when a young man gets it clearly in his head that he is made of the same kind of clay as those other men, then his only hope is not to be outstripped in

better education. He sees clearly enough, if he uses his eyes, that it is energy, grit, pluck, determination, ability to stick to it, character which makes success in the manufacturing and in the engineering world. He will finally come to the conclusion, "I can get that as well as the other fellow, I have as much grit, I can probably get more." He probably has more, and he goes back to college with the determination to get the better education.

This development of character I look upon as the greatest good that comes from work in the shop. Professor Furman, of Stevens Institute, published last winter, in the Stevens Indicator, a record of the careers of the graduates of Stevens Institute. In the group of successful graduates of Stevens Institute more than half were engaged, not in engineering, but in executive work, in managing, as presidents, vice-presidents, superintendents, managers, in some capacity in which engineering was entirely secondary and incidental, and in which the real work was executive work. Now that is a very important fact which shows what has taken place with the graduates of one of the oldest mechanical engineering schools of this country.

At college a very large amount of time is given up to the study of materials. Practically his whole chemical course is the study of materials. A very considerable part of his course in physics has to do with materials. The greater part of his work in a mechanical laboratory is a study of materials. Do you, gentlemen, realize that the great raw material with which more than one-half of the successful graduates of our technical schools have to deal, receives not a single hour of study at our colleges and universities, not one hour? That the great raw material with which the managers, superintendents, presidents, every man of our large companies is dealing is men? And these one-half of the students, who are finally called upon to manage workmen, learn nothing whatever about that at college. At twenty-two years of age on the average they land outside of college without the slightest knowledge of the great raw material with which more than one-half of them will have to work throughout their lives.

Now, those of you who have worked much with workmen, will realize fully that it is next to impossible to study them from the top. Workmen can only be properly studied side by side and shoulder to shoulder. The man who undertakes to study them from the top, gets a superficial knowledge of his workmen, and in many

cases an entirely wrong and misleading idea. The only way that a man can become familiar with the line of thought of his workmen, with the process of reasoning by which they approach the great problems that are in their minds, is by becoming intimate with them, by working side by side with them, so that they forget that you are not one of their kind, and genuinely tell you what they think.

I say without the slightest hesitation that no man is well equipped to manage workmen who cannot say ten sentences consecutively to a workman and have that workman say at once, "Oh, he has worked. I know about him. He has worked." Absolutely, unconditionally in ten ordinary sentences, if it be about work, the workman will size up the fact as to whether he has been a workman or not. And until a man is intimately acquainted with them and knows their methods of thought, their methods of expression and the way they look at things, he is at a very great disadvantage as a manager.

Just now, in this country, we are facing a great problem in the management of our men; the problem upon which, I think it may be said with almost certainty, that England has made a grand failure. We are facing that problem and are up against it hard;—the problem of soldiery, and no man can properly and thoroughly appreciate this great problem unless he has worked among men when they soldier, knows their arguments for and against it and has some idea of how to remedy that great defect; the defect which has come close to ruining the English industries.

Now there is one more thing. More and more, management is becoming a question of coöperation on a large scale. The whole training of the young man while he is at the university is an individual training. He has not the slightest training in coöperation, except possibly what he gets from his baseball or football team in the university; and yet every year the problem of coöperation becomes a greater one.

These young men at twenty-two go out without having seen any coöperation, thoroughly unfitted for it in many respects; thoroughly unfitted to do what they are told promptly and without asking questions and making suggestions. They will not become one of a train of gear wheels, and it is absolutely necessary for every man in an organization to become one of a train of gear wheels. The training he usually receives in no way fits him for that. But

the year in a shop will give him at least a good look at it. He has to work as one of a train of gears during that year. I do not think there is any equivalent for this work. Certainly the university shop is in no wise an equivalent. There they are in competition, not with men who are engaged in working for a living, but with other students. They are not rubbing against other men and getting their viewpoints, learning something as to how work ought to be done. They may get a little good out of it, but as far as the great work they ought to have, the character training and the study of men, they get nothing. The thing that comes close to it in college is the three or four months of vacation work. Even during this time, however, they fail to get it because all they do is to go in there with the idea of learning something. It is a novelty to them and they fail to get right down to the real monotonous grind which trains character. Then again, in three months, they cannot get close enough to the workmen to know their viewpoint.

Most of you gentlemen are telling your students, or advising them that they had better work as a workman for a year or so at least when they go out. About one in fifty does it. They start with the idea of serving an apprenticeship, but they do not do it. Even when they go in with the best of intentions, they cannot get away from this habit of absorbing, they cannot get down to the monotonous, to the tiresome work. They are not really learning anything. They feel that they have a fine college education and could do do that work as well as the workman, so it does not make any difference whether they work in a shop or not. And you educators say, "Oh, yes, you should take your two years course outside. It is up to you. Take a year or two years' apprenticeship." They don't do it, and they won't do it. They find themselves, when they are up against apprenticeship conditions in a shop, competing with young fellows of sixteen or seventeen. They cannot say, "There is not a single thing I do not know," and yet they are too old. Then, they are intellectually fastidious, while the young freshman who comes out gets next to the workmen better than the other. He is not, of course, so fastidious a man. He gets next to the workingman and learns much more than the other fellow.

About ten or twelve years ago I made up my mind not to take another young college graduate unless he has had two years' work outside, but, in going through the list, I found that there was a certain set of young men who were satisfactory right from the start.

Men who had by necessity been forced to leave school and go to work. So I found that I had to modify my conclusion, by saying that I would not take a man unless he had worked outside for at least two years, or unless he had worked as a workman before he graduated. I have no other reasons why these young college men were not competent, but the facts are there. That is why we came to exclude college men who had not had actual service.

Now I want to strengthen this theory by some facts. This same investigation by Prof. Furman, of the graduates of Stevens Institute, has led him to formulate at the end of the paper two sentences of the greatest importance to all teachers and to all students, as follows: "An apprenticeship of one or two years has stamped itself as the surest road to maintaining success in after life." That is his first conclusion from a study of the graduates of the Stevens Institute. A second quotation is: "A large percentage of the older graduates that now stand highest in their professional work are those who have started in as mechanical shop apprentices." That is proven by statistics, and I do not suppose Professor Furman had any more notion of those facts when he started that investigation than I or anyone else had.

One thing more, the joint committee appointed by seven of the English engineering societies, with, I think, three of the professors from universities, unanimously voted that it was desirable to have two years' apprenticeship before students graduated as engineers. I think that is a very remarkable recommendation. It goes very far toward bolstering up the theory which I have formed, that the accredited representatives of seven great engineering societies of England should recommend unanimously two years of apprenticeship before being allowed to graduate as mechanical engineers, or as any other kind of an engineer. Now, in so far as the post-graduate courses in our engineering colleges interfere with the good that the coming in touch with actual work will have, just to that extent those post-graduate courses in our colleges are bad and very much to be deplored. I do not think that the average young man needs any post-graduate course. He needs other things. He needs closer touch with actual life, and this tendency in our universities to lengthen their courses out to five or six years is a most unfortunate change. Certainly, to the average man it is a step in entirely the wrong direction.

Now, as to the liberal education, I believe that one year, con-

ducted with a totally different kind of idea of human nature under more practical conditions, with men struggling for a living is vastly more broadening than a year of travel abroad. I am very sure that in my case the thing that impressed me was the apprenticeship, and not the travel, and I feel that it has a very liberalizing effect. If I wanted to give a boy a broad liberal view, I would get him in contact with men who are really working for a living, make him see how the other half lives. That gives him a lasting sympathy for men.

One thing more, is it possible or practicable to get this year's work for a young graduate? I feel absolutely sure it is, provided those young men are sent out to work in working conditions. If they are sent out to get an education, no. But if they are sent out and made to do a day's work, they are the finest kind of raw material. Take the average young man. He has some bad ideas, but all you have to do is to mould that young man to your needs, give him character and common sense, and when the shops begin to take these young men from our universities and colleges, particularly if it becomes a regular thing, that every year from such and such a place we can get eight or ten men, the supply will not equal the demand. Now I had great difficulty two years ago in getting one of the manufacturers to take a single college man, although he was one of the most distinguished graduates of a technical school. After trying one or two of them for a year, they now want all they can get of those men. Those men come there to do the tiresome and monotonous work, and never get any notion that they are there to learn. If they should get that notion into their heads while there, they would be stepped upon like this, "You are not here to learn anything; you are here to make money for us." Now, in point of fact, they *were* there to learn. That man lost money on them every year, but they never found that out. They are there to learn, they are studying, but they never find out that they are studying, and every time they come up with a kick, they are knocked down flat.

REPAIRING HIGH VOLTAGE LINES WHILE IN SERVICE

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T HE losses suffered by most companies operating at high volt-age due to line interruptions alone are matters of great im-portance, though necessarily such losses are extremely dif-ficult to evaluate. The actual pecuniary loss, i. e., the direct loss of income due to inability to give service for a certain length of time, permits of quite accurate determination, and in some cases this is very large, depending upon the extent of territory affected and the duration of the interruption. This is, however, a very small part

FIG. 1—EMERGENCY CASE AND EQUIPMENT

Containing climbers, safety belt, connectors, come-along, test set, etc., an acety-lene gas lamp, a combination saw and hammer, emergency pole, insulator, screw clamp, hand screw and Narragansett emergency outfit.

FIG. 2—TOOLS USED IN REPLACING DEFECTIVE CROSS-ARM

Emergency poles fitted with special insulators to which are attached wire clamps for holding the line wires. In addition to the poles, there are included a light-weight reinforced hickory cross-arm with metal braces, and several adjustable clamp rings for properly spacing the emergency poles.

of the total loss incurred. By far the greater factor is the indirect loss due to the depreciation of the selling value of the power, caused by the loss of public confidence in the reliability of the service. It is practically impossible to arrive at a correct valuation of the indi-rect loss. The authors know of no company operating at a high voltage that is wholly immune from this one great source of trouble.

In an effort to avoid interruptions as much as possible, due to trouble on transmission lines, there are no doubt many operating

men who have asked themselves this question: "To what extent
is it possible to make repairs on high voltage lines without interrup-
tion of service?" Interruptions have brought this question most
forcibly to the attention of the authors, who recall this point hav-
ing been mentioned in some form or other on several occasions in
discussions and engineering publications, but do not know that it
has ever been answered or that there are any papers dealing with
this subject. It is our belief that an article describing the nature of
such repairs, method of handling same and work which has been
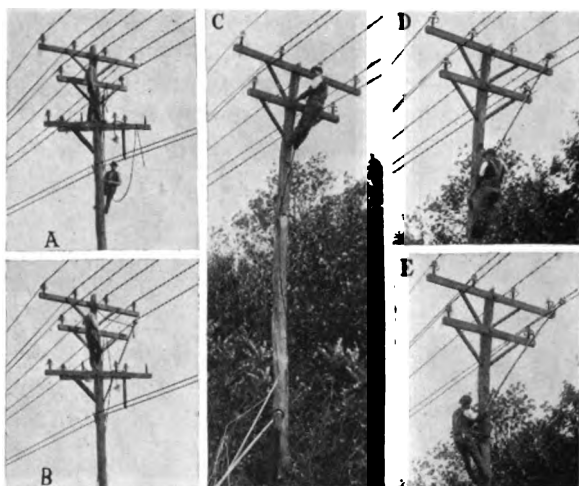
FIG. 3

A—Showing broken insulator to the right on the middle cross-arm. The
line wire is supported by an emergency pole and insulator. The pole is held
at the top by a screw clamp fastened to the cross-arm and at the bottom by
a hand screw. *B*—Defective insulator removed by sawing off pin with insu-
lated saw. *C*—Another broken insulator on extreme right of upper cross-arm.
D—Emergency pole in place, previous to removal of tie wire from the defec-
tive insulator. *E*—Line clear of the broken insulator and supported by the
emergency pole.

done with a view of eliminating interruptions on the high voltage
system of the West Penn Railways Company will prove both in-
teresting and instructive to engineers in general and to operating
men in particular.

It has been necessary for us to make this article somewhat local
in character, i. e., to make it applicable in the main to the transmis-
sion lines traversing only sections of our country which have cer-
tain climatic conditions, such as prevail in this section and in gen-
eral in the Middle Atlantic and Southern States. It is a well known

fact that considerable live line repair work has been done on high voltage transmission systems in localities where the atmosphere is very dry and the climate is not subject to sudden and severe changes, such locations being very favorable to the accomplishment of a great deal along this line, the only precautions necessary being that the workman be insulated from the ground by the wooden structure and touch only one wire at a time, and that he take the charging current of his body very gradually through some conductor on which he could take a firm grasp before bringing it within the striking distance of the line. As such conditions do not prevail in this section or in the southeastern section of our country, it is impossible to do work in this manner, as is proven by the fact that invariably where an insulator breaks down or a wire gets in contact with any part of the wooden structure, the structure is
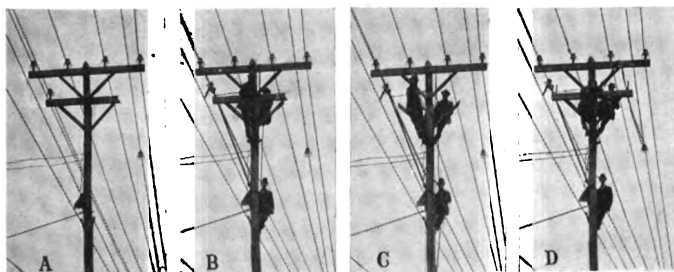
FIG. 4

A—Bottom cross-arm burned off, leaving line swinging clear. *B*—Left hand insulator removed and line wire supported from emergency pole, preparatory to removing burned cross-arm. *C*—Burned cross-arm removed. *D*— New cross-arm in place and ready to support the line wires, with hand line placed over the upper cross-arm preparatory to pulling wire in place.

burned until the wire clears itself or is repaired. Also, our climate is quite changeable, the changes often taking place very suddenly and the atmosphere contains more or less moisture at all times. In our immediate section the atmosphere also contains more or less smoke, which of itself is quite injurious to line insulation. In time the under side of the petticoats of the insulators will become covered with a deposit of dust and small particles of carbon, which deposit is continually increasing, due to the fact that the rain never reaches the under side of the insulators. Ordinary double petticoat insulators which are in use on a telephone line have been coated with a deposit having a conductivity equivalent to No. 18 copper wire. The outer surface of the insulators rarely becomes covered

with this deposit, except where conditions are very severe, as this surface is kept fairly clean by rain. Where high voltage insulators were subjected to severe smoke conditions they have been cleaned while in service as a precaution against probable trouble.

The transmission lines of the system under discussion comprise 120 miles of three-wire, 25 000 volt line constructed partly of copper and partly of aluminum, transmitting 60-cycle, three-phase current, which is transformed to two-phase by Scott connected transformers for general lighting and power service to numerous towns, manufacturing and other industrial concerns and to several street railway companies, including a portion of our own interurban railway system; also 54 miles of three-wire, 25 000 volt line, construct-
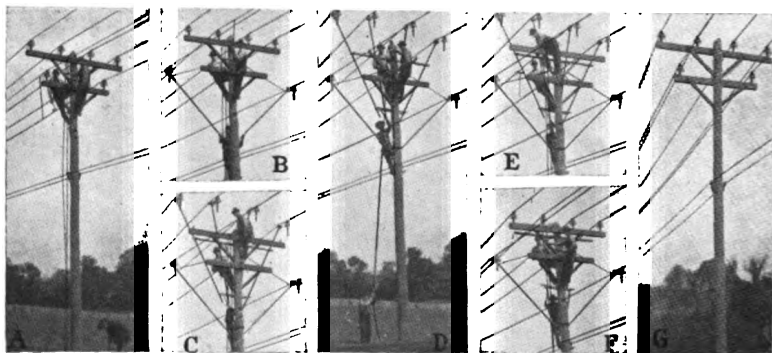
FIG. 5

A—Decayed top cross-arm; view before beginning repairs. *B*—Line wires removed from lower cross-arm and supported by emergency poles held in place by an iron fixture and rope slings. *C*—All line wires removed preparatory to removing defective arm, showing method of supporting wires. The wires are now supported at a safe distance above the cross-arm by the emergency poles, which are held in place by the hickory cross-arm fastened near the top of the pole and the iron fixture lower down. *D*—Defective arm removed. The new cross-arm is raised into position by means of a rope and a pulley attached to the top of the main pole. *E*—New cross-arm in place. The pins are next inserted and nailed. *F*—The four line wires in place, supported from the new cross-arm. *G*—Work completed and all temporary supports removed.

ed partly of copper and partly of aluminum, transmitting 25-cycle, three-phase current, which is converted by closed delta transformers and rotary converters to direct current for industrial and mining service and railway power, making a total of 174 miles of transmission line on 111 miles of poles. The transmission lines, for the

most part, traverse a rolling country, all of which is subject to fre-
quent and severe lightning storms for about four months during the
year. Between all stations where both 25-cycle and 60-cycle current
is used, the two transmission lines were built on a single pole line,
each system occupying one side of the pole line, the wires of each
system being arranged to form an inverted equilateral triangle.

Provided the supporting structure and insulation of a line are
kept in first-class condition, the liability of interruptions due to
the line breaking or burning off will be greatly reduced, as such
trouble in most cases is the result of a failure of some other part
of the construction.

The safety of men engaged on this work should in all cases
be given first consideration, and all tools, apparatus, etc., to be
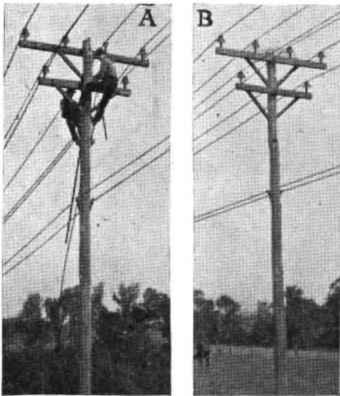
FIG. 6

A—Damaged insulator on right
side of top cross-arm. The defective
insulator is shattered with an insu-
lated hammer; the tie wire is then
removed by means of wire cutters
with insulated handles; the new in-
sulator and pin are put in place, and
the line wire is secured with a new
tie wire, using two dry wooden sticks
each having a hole at the middle
through which the tie wire is passed.
An insulated wooden mallet is also
used in tightening the tie wire.
B—New insulator in place on pole.

FIG. 7

Insulator and clamp, insulated
screw driver with hook, and pair of
insulated wire cutters used in re-
placing defective insulators. The
clamp is attached to the insulator
with its jaws in line with the top
groove and the insulator is screwed
on the pin. The jaws of the clamp
being loose, the wire is placed there-
in and the jaws are tightened by
means of the insulated screw driver.
These clamps cost more than tie wire,
but this is insignificant when com-
pared with loss due to interruptions
of service.

used in making live line repairs should have a large factor of
safety, both as regards insulating qualities and mechanical
strength.

In conclusion we wish to make a few general remarks regarding such repair work on high tension systems supported by steel towers with length of span considerably increased. This work could be carried on in a satisfactory manner and as we have above described, by simply supplying tools and apparatus of sufficient mechanical and dielectric strength for the system on which they were to be used. The workman on a steel tower is taking somewhat greater risk than the man working from a wooden structure, even though the wood is not perfectly dry, although an insulating stage could be designed and supported from the tower, thereby reducing this risk to a certain extent. At the same time the weight of the wire which must be supported would
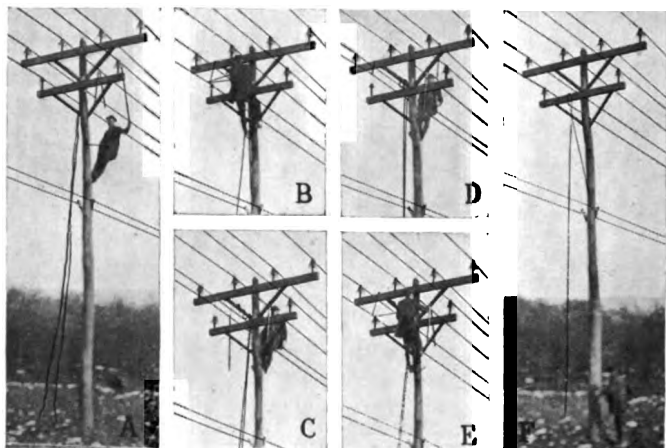
FIG. 8.

A—Broken insulator on lower cross-arm, previous to beginning the repair. *B*—Detaching the tie wire from a broken insulator by means of the insulated wire cutters. *C*—Line wire clear of the broken insulator on the left and supported by hand line. *D*—New insulator in place with clamp attached. *E*—Workman clamping line wire to the new insulator, the wire being guided by the insulated hook and the jaws tightened by the insulated screw driver. *F*—The repair complete, the wire being securely held by the clamp.

be increased, due to the greater distance between supports or the use of heavier wire. In some cases this weight may be so great that even several men could not lift the wires, in which case a jack or some such device would have to be provided.·

NOTE.—The methods devised by Messrs. Jenks and Acker for repairing high tension lines while in service are illustrated in the accompanying cuts. A detailed description of the various appliances and the way in which they are used was given in *The Electrical World* for August 5, 1909.

THE CHOICE OF A CONDENSER (Cont.)

FRANCIS HODGKINSON

AIR PUMPS

In general the design of air pumps is the same whether used for jet or surface condensers, except in the matter of volumetric capacity. This discussion, therefore, covers air pumps for either type of condenser.

It is an interesting fact that the earliest design of wet air pump as built by James Watt is about the best. This pump, shown diagrammatically in Fig. 7, is built to work vertically and arranged to run with fine clearances, and, with well designed valves, in spite of its antiquated design, can be made as effective in giving a high vacuum as most any other yet built. It may be used very effectively as a dry air pump, provided some cooling water be admitted through a check valve, as at *A*. This serves to keep the clearance spaces full and water seal the pistons and valves, preventing the leakage of air. Any leakage is thus in the form of water instead of air. When used as a wet air pump, this sealing water is, of course, not necessary, but if the water leaving the condenser is at a temperature approaching that of evaporation (at the pressure within the condenser), the auxiliary supply of water betters the performance of the air pump. Since the pump works vertically the water tends to spread itself over the surface of the bucket or piston and the valve decks. Obviously, so long as this water is not worked up into a commotion, the pump has *no clearance* and *no leakage,* which is, of course, the first desideratum of an air pump.

FIG. 6—VERTICAL CONDENSER SHOWING PIPING AND VALVE ARRANGEMENT.

Referred to as Fig. 5 in August issue, p. 482.

The objection to the design is that there are three decks of valves which are more or less inaccessible. These are generally made of soft rubber, seating on a metal grid. Frequently they have no springs. With reciprocating engines, rubber valves do not last well because the presence of oil rapidly decomposes them. In these

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cases thin phosphor bronze discs are employed. With turbines this objection is not encountered·due to the absence of oil.

There have been various modifications and improvements in this type—one being the elimination of the foot valve. A further simplification is embodied in the Edwards pump, shown in Fig. 8. This pump has no valves other than the head valves, which *may be examined while the pump is in operation.* It is seen that the conical shaped piston descends below the port *A,* permitting the non-condensable vapors to be drawn in above the piston and the casing is so formed that the piston will splash up what water is in the bottom into the space above with an injector action which helps to carry the air with it. The water and air above the piston are then ejected through the head valves on the upward stroke. This design of wet air pump is used very extensively in Europe.
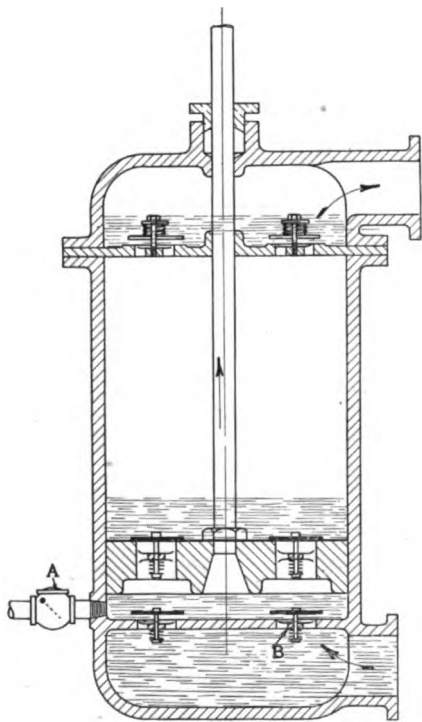
Another form of air pump not unlike the Edwards, but arranged to be operated horizontally, is shown in Fig. 9. Like the Edwards pump, it has delivery valves only, the air being drawn in by the piston through the ports shown in the center. So long as this pump is operated very slowly so that the water will rise and

FIG. 7.

fall in the barrel without commotion, good results will be obtained; but, as soon as considerable piston velocity is attained, the water will pile up in front of the piston forming a wave or vortex (as shown in Fig. 9), in the interior of which is a pocket of air which does not escape through the discharge valves. This very naturally decreases the usefulness of the pump by re-expanding when the piston recedes. This pump is used both as a wet and a dry air pump. In the latter case a stream of water is let into the pump for the dou-

ble purpose of cooling the non-condensable vapors, filling the clearances so far as possible and water sealing against leakage.

A very common form of wet air pump is that shown in Fig. 10, and it is subject to the same disadvantages as that shown in Fig. 9 which, however, may be largely overcome if the design is modified as indicated in Fig. 11. The trouble (Fig. 10) is that on the suction stroke the amount of water left in the clearances is not enough to keep the pump barrel full until the piston reaches the end of its travel. In the design suggested in Fig. 11 the *effective piston* is not the horizontal working piston at all, but rather the *up and down motion of the water*. This design obviously entails the use of a large amount of cast iron and relatively large dimensions for a given capacity, which, it may be supposed, is the reason for its limited use.
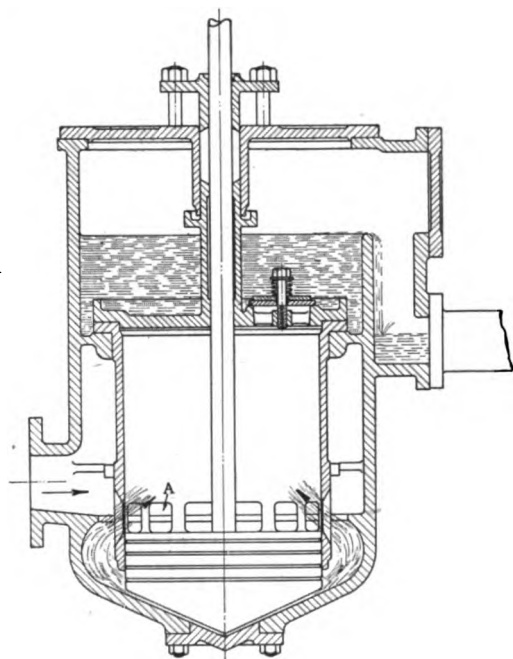
FIG. 8.

Fig. 12 shows a very interesting type of old-fashioned pump, drawings of which are to be found in old books, and is a striking example of the horizontal motion of a plunger being transformed into vertical motion of the *effective* piston (the water). There are recorded tests of these pumps in which the volumetric efficiency is quite a little over 100 percent due to the momentum of the fluid.

So far as wet air pumps are concerned, it is a fair general statement to say that it is only the vertical pump which may be regarded as highly effective, unless special precautions are taken to avoid eddies and vortices as indicated above, and this involves extra cost of construction.

Only those types which may be used as wet air pumps have been described, but in conjunction with the discussion of arrange-

ments of surface condensers reference has been made to the rotative type dry air pump. This must be used to handle air only. Since it has pistons like a reciprocating engine, the presence of any quantity of water would obviously have disastrous results. Hence it should always be arranged in such a way that water cannot reach it from the condenser. An air pump of this type is shown diagram-
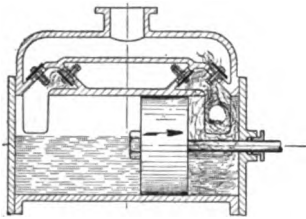
FIG. 9.

matically in Fig. 13, two tandem pumps being shown in this case. One pump of similar construction is frequently used. The double ported D-slide valves B, the eccentric for which is set exactly 90 degrees behind the crank, control induction only; ejection occurring through the spring-loaded poppet valves A. One special feature usually employed in this pump is the flash pot B. This connects the opposite ends of the cylinder when the piston reaches the end of its stroke and the valve is at mid-stroke traveling at its maximum velocity. The piston having reached the end of its stroke has compressed and discharged a part of the air through the poppet valve A. That remaining in the clearance space is at approximately atmospheric pressure, and is then allowed to by-pass through the flash port to the opposite side of the piston where there is vacuum and where the induction valve has closed and the piston is about to start compression. This equalizes the pressure at the ends and permits the piston almost immediately to commence to draw in a new charge on its suction stroke, instead of re-expanding and re-compressing the same particles, which would cause unnecessary heating of the air and thus reduce the weight of the air that the pump can handle. At the end of the stroke when the piston has drawn in its charge of air, the pressure (vacuum) is the same as that of the

FIG. 10.

condenser. Then the induction valve closes and the flash port opens, admitting air from the clearance space on the other side. This increases the pressure in the cylinder a small amount before actual compression by the piston commences. It is thus seen that the flash port contributes largely to the efficacy of the pump for the two reasons explained above. Inasmuch as a compression of 17 fold takes place, the work done per pound of air is very high. A large amount
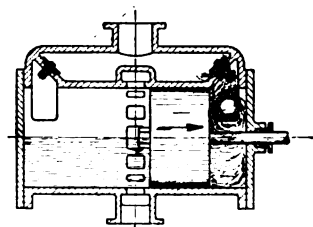
of heat is generated and water jacketing of the air pump must be resorted to. If there are any air leaks the temperature sometimes is high enough to carbonize the lubricating oil, closing up the passages.

Dry air pumps are sometimes built in two stages, Fig. 13; that is, a single steam cylinder drives two tandem air cylinders. The air pumps are arranged like two pumps of a compound air compressor, but with the two pumps identical—i. e., having the same displacement. The advantages of two identical cylinders are, besides those of interchangeability of parts, that by means of two cylinders the one drawing direct from the condenser has very much less weight of air in the clearance space, thereby largely increasing the capacity. As the cylinder displacements are equal, one will obviously do nearly all the work, say, from 27 inches vacuum to atmospheric pressure, while the other compresses, say, from 28 or better to 27 inches. Thus the air in the clearance space of the pump drawing direct from the condenser at the time of maximum compression is at a comparatively high vacuum and the piston has to recede little before beginning to draw in a new charge; in other words, the clearance weight is a minimum. Incidentally the glands and such leakage in the pump are connected to its discharge, thereby keeping the leakage at a minimum.

FIG. II.

There is yet one other type of air pump, the Leblanc, now becoming known in this country. It is exceedingly simple and consist of a revolving wheel carrying buckets which impel a

FIG. 12.

series of laminations of water down a suitable diffusing tube. These laminations or chunks of water entrain some air with them by friction, but the greater quantity by enclosed air between the laminations. This type of air pump is remarkable in that it can readily
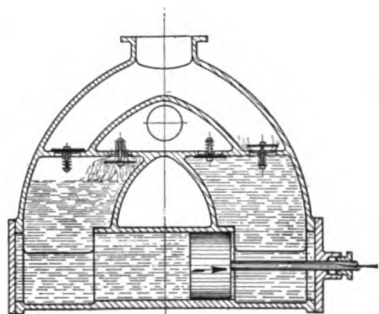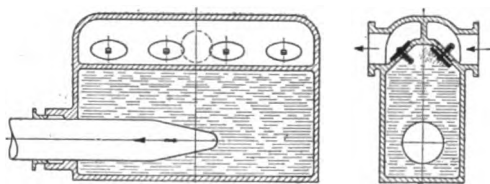
produce a vacuum corresponding to the pressure at which evaporation of the water within the pump will take place.

AIR PUMP CAPACITY

The displacement of a dry air pump or a wet air pump for use in connection with a surface condenser, is rather difficult to estimate; in fact, it is generally done arbitrarily. If there were no air leaks either in the exhaust piping, condenser, engine or feed pump systems, the air pump displacement required would be about that of the feed pumps. Some designers provide in connection with a surface condenser the same displacement whether in a wet or dry
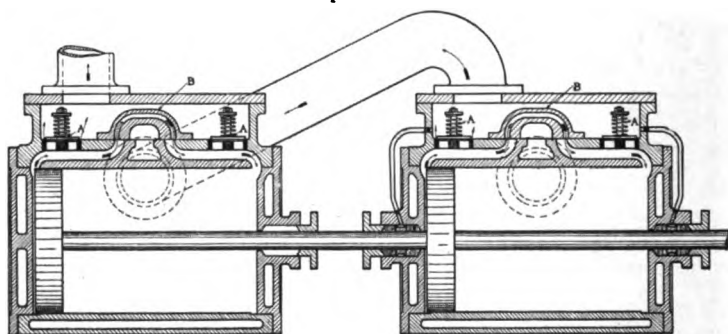
FIG. 13.

air pump that would be used in conjunction with a jet condenser of same capacity. In the case of the latter, there is some basis on which to estimate the volume, viz., the air entrained in the cooling water which is usually taken at five percent by volume at atmospheric pressure; i. e., one cubic foot cooling water containing one-twentieth of a cubic foot of air, so for 28 inches vacuum for each cubic foot of cooling water the air pump requires fifteen-twentieths of a cubic foot of displacement of air. English and German builders of surface condensers provide 1.5 cubic feet air displacement for each pound of steam condensed.

There is a great inconsistency on the part of condenser builders as they invariably guarantee a certain vacuum with given injection temperature, providing the piping and the engine whose steam is to be condensed "are free from air leaks"—an obviously impossible condition which the condenser builder plainly recognizes by invariably furnishing an air pump of considerable dimensions to remove air specified not to be present. Hence some

means of ascertaining the volume of air in exhaust steam would be of great value, when a condenser specification might be written to handle a specific quantity of air. Merely measuring the temperature would accomplish this except that the temperatures to be read would be so exceedingly close to that of saturated steam that it would be impracticable to read the temperature with sufficient accuracy to make even an approximate determination.

A method has been suggested of passing the delivery of the air pump to the interior of an inverted bell floating in water in the manner of a gas holder, the sides of the bell being furnished with a vertical row of holes of suitable size for the exit of air. The amount of air passing would be measured by the flotation of the bell and the number of holes above the surface of the water.
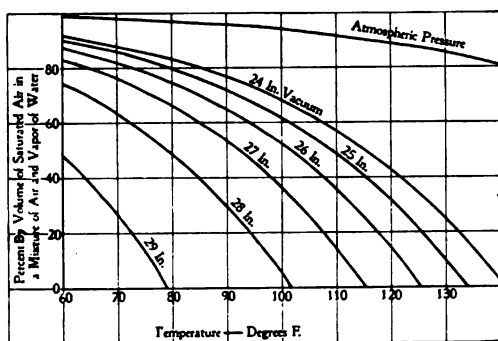
FIG. 14.

Another determination is as follows: Having given the displacement of an air pump, the temperature and the pressure at the suction, the air passing may be calculated from the data given in Table I*—here reproduced as a curve, Fig. 14. Suppose there was a 27-inch vacuum in the air pump suction and the temperature was 110, then approximately 14 percent of the displacement of the air pump is the amount of air being handled. Here may be shown the importance of care being taken in design to insure effective cooling of the air either before it leaves the condenser or on its way to the air pump suction. In the case just cited, had the air pump suction been 90 degrees instead of 110, the air passing would have been 53 percent of the displacement. In the latter case the air pump would be in position to handle, $\frac{53}{14} \times \frac{461+110}{461+90} = 3.92$ times the volume of air, or the air pump displacement might be reduced in the above ratio.

It is not seriously suggested that these figures might be a basis for calculating the air leakage because it is almost impossible to

determine the displacement of the air pump when operating with such low density air. The least leakage in the valves, fluid friction through the ports, etc., affect the actual displacement enormously.

In drawing up specifications for a dry air pump it is a good plan to stipulate a certain displacement and also stipulate that with a closed suction it will be able to maintain a vacuum within so much of the barometer. Within two-tenths of an inch of mercury is regarded as high performance and the pump is of reasonably good workmanship and proper attention has been given to clearances, etc., in the design. A pump that will pull but to one-half inch may be regarded as ordinary. In actual practice a pump will not be able to produce a vacuum so close to the barometer as the above figure because of the unavoidable air leakages in the system. Furthermore, in properly arranged condensers, this is not even necessary, as will be shown in the discussion on counter-current jet condensers. It would be convenient to specify that an air pump shall produce a given vacuum with the suction pipe closed except for a certain sized orifice open to the atmosphere through which air may be pumped, in this way specifying the volume that the pump must handle.

One rather interesting fact in connection with dry air pumps and the power required for their operation is that it is necessary to provide sufficient driving capacity to overcome the point where the greatest power is needed. Obviously, when there is no vacuum in the condenser and the pump is simply transferring atmospheric air from the inlet to the outlet, substantially no work is being done. Similarly, when there is a perfect vacuum in the condenser, the compression and expansion line on the indicator card will be coincident; in other words, the card will have no area and hence again no work will be done. There is then a point between no vacuum and a perfect vacuum where the power required is a maximum. In actual practice the maximum card and work occurs at about 21 inches vacuum and there must be enough capacity to drive the pump at this time.

A word might be said regarding the vacuum augmentor introduced by Mr. Parsons, see Fig. 15. A small auxiliary surface condenser, *A*, is employed into which flows a jet of steam from nozzle *B* through suitably formed combining tubes *C* which draw non-condensable vapors from the condenser pipe *D*. The ejector then constitutes a first stage air pump capable of handling enormous volumes of air, but at a very low pressure head. It increases the condenser pressure

from 1 to 1.5 inches, from which the regular air pump raises it to atmospheric pressure. The air essentially passes along the path *E* and the water along *F*. The elevation of the water level is higher in *F* than in *E* because of the difference of pressure caused by the jet. Obviously the requisite vertical height must be provided in *F* on account of this, and it is further necessary for a seal to prevent air from the jet circulating back to the condenser. The writer has been informed that in an installation of from 4 000 to 5 000 kw capacity the augmentor requires 750 pounds of steam per hour, increasing the vacuum one to 1.5 inches, bringing the surface condenser performance very close to the ideal, viz., to four degrees F.
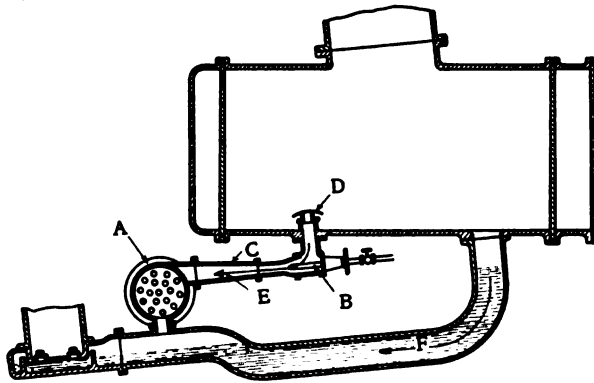
FIG. 15.

difference between exhaust steam and outgoing cooling water, which is a most remarkable performance.

FREE EXHAUST VALVES

As atmospheric exhaust valves are vital auxiliaries to condensers, a word about them is in order. They are manifestly a necessity, for without them an accident to the condenser may result is bursting the condenser shell (if of surface type), or the low pressure section of the turbine. As air leaks are of serious importance and the valves are generally made large enough to permit the engine to carry full load when operating non-condensing, every means must be taken to insure their being absolutely air tight. Furthermore, they must be of simple construction and arranged so that there is not the least danger of their failing to open when required.

With turbines the problem is simpler than in the case of a reciprocating engine, inasmuch as the exhaust from the turbine is

less intermittent, and hence dashpots are not as necessary. Further-
more, as the exhaust is uncontaminated with oil, valves with rub-
ber seats may be used, the seats lasting almost indefinitely. In large
units with free exhaust valves made entirely of metal two feet or
more in diameter, it is hardly to be expected that they could be kept
tight and, in fact, they never are; so that, wherever possible, rub-
ber rings should be resorted to. In one type of valve the rubber
rings have been applied as shown in Fig. 16. Provision is usually
made for a water seal,
but with the rubber
ring, unless some for-
eign matter gets under-
neath the seat, this does
not often need to be
used. One important
feature in the construc-
tion of these valves is to
have the guides, etc., so
disposed that by no
combination of circum-
stances can the valve be
prevented from aligning
itself on its seat. A
hand wheel, or other
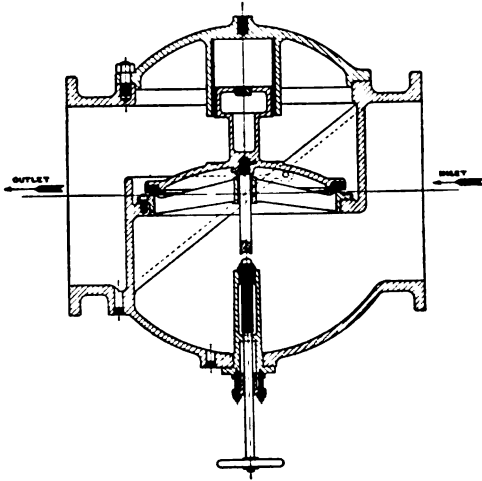
FIG. 16.

means, sometimes a counter-weight, is always employed so
that the valve may be propped open for running con-
tinuously non-condensing when desired. Whatever the means, it
must be such that nothing holds the valve on its seat except atmos-
pheric pressure. As the safety, as well as the successful perform-
ance of a condenser, is dependent upon the operation of the free
exhaust valve, the cheap valves that are to be found on the market
should be regarded with suspicion, not only to insure the use of a
valve absolutely tight, but one that will assuredly open freely when
required and will not be rusted after remaining closed for long peri-
ods. The valve stem should be of brass, passing through a bronze
bushing. The dashpot, if one is employed, should have a brass
faced piston and brass lined cylinder. A first principle in installing
a free exhaust valve is to be sure there is no gate valve between
it and the turbine exhaust.

(To be continued.)

EXPERIENCE ON THE ROAD

POWER PLANT OPERATION

H. L. BEACH,

Electrical Engineer, Pennsylvania Coal & Coke Company

WHEN the writer took charge of the plants now under his direction he was informed that some difficulty had been experienced with the generators at the largest plant in the district. This plant consists of two direct-connected, 25 cycle, three-phase alternators of 300 and 400 kw capacity respectively, driven by horizontal non-condensing engines. Both generators operate at 5 600 volts, the 400 kw machine running at 125 r. p. m. and the 300 kw machine at 187.5 r. p. m. The load on this station consists of a 5 600 volt synchronous motor driving a 250 kw, 275 volt direct-current generator and three 250 kw 275 volt, rotary converter sub-stations. The direct-current load is a typical railway load. The switchboard was so designed that the two generators could be run separately or in parallel. When run separately it was necessary to operate the rotary converters from the 300 kw generator and the 250 kw motor-generator set from the 400 kw generator. The main generators could be excited either from their own belt driven separate exciters or from the motor-generator set, or from an independent direct-current unit that was ordinarily used for town lighting purposes and could be switched on if required. It seemed to make no difference how the machines were excited as the results were the same. Usually the excitation was taken from the motor-generator set.

It was stated that the 400 kw unit would lose its voltage, and consequently its load, at almost any time. The trouble was thought to be due entirely to the 400 kw generator. Two experts had been sent to correct the trouble before the writer was acquainted with the plant and another at the time he took charge. This last man reported that the operating men were ignorant and could not run a modern alternating-current machine, that the rotary converters were allowed to run at a higher voltage than the motor-generator set, thus the higher direct-current voltage from the rotaries overbalanced the lower voltage of the motor-generator set, causing it to reverse its polarity, which in turn reversed the field excitation of the synchronous motor and caused it to fall out of step and pull

down the generator voltage. At the time of the writer's first visit all of the machines were getting their excitation from the motor-generator set. If anything happened to it the voltage of the whole plant went down. The expert also claimed that the synchronous motor was highly over-excited and that the leading current thus forced through the armature of the main generator, caused the operators to carry a weak field on the main generator. The two main units were not being run in parallel for reasons which will be described later.

The expert looked over the entire plant and gave orders to increase the voltage on the direct-current generator of the motor-generator set, increase the excitation on the 400 kw unit and decrease the excitation on the rotaries so as to reduce their voltage by causing a heavy lagging current in the line and thus a large line drop. He claimed that the rotaries, being compound wound, would correct this as the load came on. The trouble, however, did not disappear, and it has since developed that the series field in one of the rotaries was reversed so that instead of building up the voltage, it lowered it as the load came on.

In order to properly investigate the causes of the trouble, the writer started at the beginning and looked up the specifications and guarantees of the machines, discovering among other things that the engine connected to the 400 kw machine was designed for 125 lbs. throttle-pressure, while they were carrying from 80 to 100 lbs., and the safety valves on the boilers were set for only 115 lbs. The setting of the safety valves was changed to 140 lbs. and the pressure carried to 135 lbs., with the result that the unit gives absolutely no trouble, and has never failed to hold up its voltage, under the worst conditions of fluctuating load and heavy overload.

When the writer asked the operators to run the two machines in parallel all the time, as the load was too heavy on the 300 kw machine, he was told that they would not run in parallel. This developed the fact that the machines hunted so badly when connected together that the governor of the 400 kw unit bumped the wheel of the engine very viciously. At best, whenever the two units were together the revolutions of the 400 kw unit could be counted as accurately with a direct-current volt-meter connected between the trolley wire and the rail at the far end of the trolley line, as they could be counted when standing alongside the engine.

The writer again went after the engine instead of the generator. This type of engine has a very sensitive governor, which is

not supplied with a dash pot. The makers claimed that a dash pot was entirely unnecessary, but, after their man had experimented with one with good success, it was decided that "a dash pot has a very soothing effect upon the operation of an engine running an alternator" to quote from the engine people. Since the addition of this piece of apparatus to the engine, it has been found perfectly feasible to run the units together, but the long run of trouble experienced had given the large unit such a bad name that every time anything happened, the first thing the operators thought of doing was to pull out the switch between the two alternators, shifting the bulk of the load to the 300 kw unit. To stop this, the writer had this switch cut out entirely and the two machines connected to the same bus-bars, through their own switches and the switch which was formerly used between them is now used as a disconnecting switch to cut out the outside lines. The plant now runs very satisfactorily and the men are really getting to like the "big" unit as they call it.

PARALLELING TWO DIRECT-CURRENT GENERATORS

The original plant in this case consisted of a 150 kw, 220 volt, compound-wound generator direct-connected to a horizontal non-condensing engine running at 200 r. p. m. A new unit was purchased of exactly the same size and speed but for 250 volts and of a different make. It was at first said that it would be impossible to run the two machines in parallel on account of the different compounding characteristics and on account of the lower voltage of the old generator. The writer, however, had the switchboard built for parallel operation. The old generator was thoroughly overhauled after the new machine was running. When repairs were completed the machine speed was raised a few revolutions per minute when the higher voltage was found to be easily obtainable with quite a little of the field rheostat in circuit.

As the compounding characteristics of the two machines were known to be different, a frame of grid resistance was procured and mounted alongside the old generator so as to be available for shunting the series field and thus equalizing the compounding. The machines were then paralleled and an attempt made to equalize the load by adjustments of the shunts on the two fields. It was found that the old machine would take two-thirds of the total load and no adjustments of the shunts would alter the result. It then occurred to the writer that the resistance of the series field of the old

machine was so much less than that of the new that no matter what shunt was used the current would divide so that more would go through the old field than the new. The grids in the frame were accordingly connected in parallel and the resistance thus obtained was connected in series with the series field of the old machine. The machines were then connected in parallel when it was found that the load divided absolutely evenly throughout the entire range of the machine.

The results of this experience have led to the conclusion that, contrary to usual practice, the proper way to get proportional loading on two compound-wound direct-current generators is to adjust the resistances of the two series fields in inverse ratio to their kw capacities and then adjust with shunts for equal compounding if desirable. The writer has proven to his satisfaction, however, that a machine much over-compounded will parallel successfully with a machine of even compounding, provided the resistances of the series fields are properly adjusted.

THE JOURNAL QUESTION BOX

296—RE - CONNECTING TWO - PHASE INDUCTION MOTOR FOR THREE-PHASE—A two-phase induction motor of the following characteristics is to be re-connected for operation on a three-phase circuit — capacity, 50 hp; voltage, 220; speed, 900 r.p.m.; 60 cycles; six coils per pole, eight poles per phase, 96 coils total. With the coils regrouped, 32 per phase, eight poles of four coils each, what voltage should be supplied for the star or delta connection?

<div align="right">D. C. M'K.</div>

There is nothing to indicate in the question whether the eight groups per phase are all in series or in one or more series—parallel groups. If the groups are in series, by re-connecting for three-phase—eight-poles, the groups per phase being all in series and the three phases being connected in star, the motor should be operated on a 275-volt, three-phase circuit in order to obtain approximately the same performance as when operated on two-phase, 220 volts. By connecting the motor with all the groups per phase in series and the phases in delta, the three-phase voltage should be 160 volts. If the two-phase, 220-volt winding is obtained by connecting the groups per phase in two parallel circuits, the corresponding voltages for the above star or delta connections are 550 volts and 320 volts, respectively. By placing the groups per phase in parallel and connecting the phases in star or delta, the primary voltage should then be 275 volts, or 160 volts, respectively. It would hardly be advisable to change the voltage more than 10 percent above or below that suggested, since the performance characteristics obtained under

such conditions would probably not be good.

<div align="right">M. W. B.</div>

297—SMALL HIGH SPEED ALTERNATING-CURRENT MOTOR—Would it be possible to build a high speed, small power type of induction motor to fulfil the following conditions: R.p.m., 8 500-8 600; maximum hp, 0.03; desired max. diameter of the stator casting 2 11/16 inches? The diameter of the stator casting might be increased by two inches, if necessary. This high speed would of course necessitate high frequency even with two poles. The power per motor is small; however, a large number of motors would be used in the application in view. Would it be possible to build a frequency changer set having an output of 120 to 150-kw to change from 60 cycles to the higher frequency? If a high frequency generator were driven by a direct-connected 60 cycle, synchronous motor deriving its power from a 60-cycle generator having good speed regulation, would not good speed regulation be assured for the small motors? If an induction motor were used in the frequency changer set in place of the 60-cycle synchronous motor, would not variations in load on the high frequency generator result in changes in the speed of the motor and therefore give poor regulation of the high speed motors? Could a high frequency generator be built for direct-connection to a 200 r.p.m. reciprocating engine?

<div align="right">A. F. E.</div>

The above conditions of design can doubtless be met without serious difficulty both as regards the small power motors and the high frequency generator. With two-pole motors a frequency of 140 to 145 cycles per second would be required to obtain a motor speed of 8 600 r.p.m. The use of a synchronous motor in the frequency changer set would insure speed regulation in the motor corresponding exactly with that of the 60-cycle source of power; whereas, the use of an induction motor would involve more or less slip, depending on the load on the high frequency generator.

In the frequency changer set, the use of a direct-connected standard ten-pole, 60-cycle motor, giving a speed of 720 r.p.m., and a 24-pole generator operating at this speed, would give a frequency of 144 cycles and a synchronous speed of 8 640 r.p.m. for the two-pole small power motors; closely approximating that required. A high frequency generator possessing these design characteristics would have to be specially developed, and would therefore be found to be much more expensive than if a standard machine could be used. It might be possible to obtain a standard machine to fulfill the requirements by over-speeding. In this case the question of its mechanical strength would be involved. It would not be possible to design a generator for direct-connection to a 200 r.p.m. reciprocating engine, as the number of poles required at this speed, with a machine of the capacity involved, would be prohibitive. If the use of a reciprocating engine must be considered, the most practicable arrangement would be obtained by employing a standard 133-cycle generator belted thereto. With the use of pulleys of proper diameters an over-speed of approximately nine percent could be obtained, without involving any objectionable features of operation, which would give the desired frequency for the small power motors. For example, a standard machine of the following characteristics could be obtained: 120-kw, 2 200 volts, single-phase 12-poles, 1 330 r.p.m., 133 cycles. This, of course, would require the use of step-down transformers to obtain the proper operating voltage for the small power motors. If constant speed characteristics are essential, the somewhat inferior regulation of high-speed reciprocating steam engines should be considered.

The speed regulation of the small power motors would be identical with that of the motor-generator set if synchronous motors were used, but the complications involved render this type of motor unsuited to this service as the size of the motors is so small. The practical solution lies in the use of polyphase induction motors. H. M. S. and C. P. M.

208—DRYING OUT TRANSFORMER OIL —In an article by Mr. S. M. Kintner, in the JOURNAL for October, 1906, p. 583, a method of removing the moisture from transformer oil is outlined. A temperature of 105 or 110 degrees C is recommended where a vacuum is not used. In using this method for drying out oil, would 90 degrees C be sufficient where an 18-inch vacuum is used above the oil, the exterior temperature being 25 degrees C? Please give data necessary for the construction of an iron rod or grid resistance to be connected to a three-phase, 230-volt, 60-cycle circuit, the current not to exceed 50 amperes and the possible variation of the line voltage being 220 to 240. It is proposed to use this resistance in heating the oil to the proper temperature to remove the moisture. The oil will be contained in a steel tank four feet in diameter and 30 inches high, and constructed of ⅝-inch plate, holding, when two-thirds full, about 150 gallons. It is of course understood that the grids should not reach a temperature sufficient to burn or carbonize the oil if, for example, a quantity of the oil were drawn off by mistake. The apparatus will be so arranged that cold oil may be introduced at any time and in any quantity and the pump will be capable of removing the dried oil even with the vacuum maintained over the oil. J. H. S.

With a vacuum of 18 inches, about 80 or 90 degrees is sufficient to dry the oil. The amount of energy required to keep the oil at a constant temperature would be *very much decreased* if the tank were covered with some non-conducting material to reduce the radiation. Asbestos lagging would probably be found to be most effective. An *unprotected* tank of the size specified would dissipate about two kw with an oil temperature of 90 degrees C. A grid resistance of three or four frames such as those ordinarily used in electric railway car equipments, capable of dissipating about 2.5 to 3 kw, would be suitable. The resistance would be so low, however, that in order to ob-
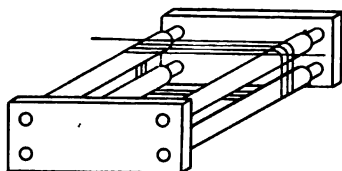
FIG. 298 (a)

tain the right amount of energy, it would be necessary to lower the voltage impressed on the grids. This, of course, could readily be done if a transformer of the proper design were available. If the grid resistances are not obtainable, a resistance can easily be constructed by winding wire on a frame made by supporting four iron pipes at each end by wooden blocks as shown in Fig. 298 (a), the pipes being insulated by wrapping each with three or four layers of asbestos paper. About 2 000 feet of No. 14 iron wire will be required if 230 volts is used. For this reason it would be advisable to lower the voltage by means of a transformer or a water rheostat and use less wire. A good idea of how to make a water rheostat can be obtained by referring to No. 220 in the JOURNAL for March, 1909. It will not be necessary to use more than one phase of the three-phase circuit for supplying the energy to the heating coils. The dielectric strength of the oil should be tested at intervals by the conventional air-gap method as described in the

JOURNAL for February, 1905, p. 98. It will be necessary to have a thermometer in the tank to indicate the temperature of the oil.

The above method of drying oil has a serious disadvantage, for, at temperatures above 75 or 85 degrees, a more or less perceptible disintegration of the oil takes place if the temperature is maintained for a considerable length of time. The experience of recent years has shown that at a temperature of about 90 degrees or more the deterioration rapidly increases and results in serious injury to the oil. Referring to p. 587 of the article mentioned in the question, it will be noted that, for this reason, there is a strong recommendation against the use of this method and in favor of the method of de-hydrating described therein. If an apparatus such as the one mentioned is not available, a comparatively effective though crude method of raising the dielectric strength of the oil is that of placing in the oil one or two sacks of lime. This material readily absorbs the moisture in the oil. The lime should be well burnt, of a soft chalky character, and tend to crumble when handled. It should be broken up into pieces about half an inch in diameter. The lime has no harmful effect on the oil when used in this way.   I. E. C.

299—THREE-PHASE — SINGLE-PHASE TRANSFORMATION — Could a transformer be devised that is three-phase on the primary side and single-phase on the secondary?   E. R. R.

A discussion of this question and the demonstration that it is impossible to obtain efficient operation and balanced conditions at full load, is given in an article by Mr. Chas. F. Scott, appearing in the JOURNAL for February, 1906, p. 43.

300—OPERATION OF STARTING RESISTANCE—With a standard starter and resistance for starting a 240-hp motor against one-half load in 30 seconds, once every two hours, what hp is the starter capable of handling under the following special conditions? (a)—Starting against an overload, *e. g.,* 100 percent

motor load or 100 percent motor overload, other conditions remaining the same; (b)— Starting under the conditions given but in a shorter or longer time than 30 seconds; (c)— Starting under the conditions given, but more frequently than once in every two hours; (d)—If the load, time of acceleration, or the frequency of starting is changed, do the other conditions also vary or can they be kept constant? (e) —Can the relations between these conditions be expressed by a formula?   J. C. C.

Resistance designed for use in starting motors, etc., may be classified into two general types; those inherently possessing considerable momentary heating capacity due to their being so arranged that a large amount of heat energy may be absorbed by the large volume of material used in the conductor itself, or by the material in which the conductor is imbedded. A resistance of this type is suitable for handling sudden current overloads but requires a comparatively long time for cooling. Resistances of the other class are those possessing comparatively small momentary overload capacity but arranged to have large radiating power. The latter are therefore serviceable for use where a resistance is required for reasonably constant capacity. It is obvious then, that the effect of the conditions stated in the question depends on the inherent characteristics of design of the resistance itself. The following, however, may be noted: (a)—Heating increases as the square of the current; hence, 100 percent load would give four times normal heating, 100 percent overload would give 16 times normal heating; (b)—Assuming that the hp remains constant, the time of starting only being decreased, the shorter duration of load on the resistance would result in correspondingly low heating. If the starting conditions involved increase of power in order to obtain a shorter period of acceleration due to the starting characteristics of the motor, the increase in heating due to the larger current might be found to offset or even overbalance the decrease of heating

which would be expected because of the shorter period of time involved. If the resistance used were of the first class, mentioned above, the effect of the starting conditions would depend upon whether or not the frequency of starting would allow for the necessary time of cooling of the resistance units; if of the second class, increase in the frequency of starting would have no effect until a point was reached where the radiating power of the resistance was exceeded; (d)—It is evident from the foregoing that variation in any one of the conditions will affect the total amount of power involved; hence one of the conditions cannot be varied without change of one or both of the others being necessary, unless, as noted in (c) the resistance ·is of the second class and its radiating power is not exceeded; (e) —Each case obviously requires individual consideration. See also "Notes on Rheostat Design" by Mr. F. D. Hallock, in the JOURNAL for February, 1907, p. 105.   H. C. N.

301—RATING OF CIRCUIT BREAKERS —A certain standard commercial form of high-tension oil circuit breaker is made in two sizes, viz., for 66 000 volts and 88 000 volts and in current carrying capacities up to and including 200 amperes. The ultimate breaking capacity of these circuit breakers is rated as follows: Single-phase, 12 000 kw; two-phase, 30 000 kw, and three-phase 20 000 kw. From this it would seem that a 200 ampere, 88 000 volt circuit breaker, operating single-phase, would not open a circuit carrying a current equivalent to the normal rated current capacity of the circuit breaker, at a line voltage of 88 000 volts. Please explain this seeming discrepancy.   R. F. H.

In the design and application of circuit breakers there are certain governing conditions which determine the proportions of the various parts and the amount of power which can be handled by the complete device. In high-tension circuit breakers, in which the insulation distances must be great and in which the current carried by any part is small,

mechanical stability necessitates making the current-carrying parts of larger size than would actually be required to give the current capacity indicated by the limits of its application. In order to define the actual current-carrying capacity of such a piece of apparatus, it is the custom to give a maximum current rating as well as the maximum voltage rating of the breaker. It may develop, however, that the circuit breaker is not sufficiently rugged in construction to withstand the shock or dissipate the energy incident to the opening of a short-circuit on a system capable of supplying power equal to the maximum ampere capacity of the circuit breaker at its maximum voltage. In order that the application of the breaker shall be limited to systems capable of delivering at the breaker an amount of energy, on short circuit, which is within the opening capacity of the device, a safe "ultimate breaking capacity" is determined for each particular type. As noted above, then, the determining factor in the selection of the breaker which may be used in any given case is the power which may be developed at the particular point at which the breaker is located. For instance, considering a power system including a central station with outlying sub-stations, some of which are at the end of a long transmission line; the generators are connected directly to bus-bars in the station, and from the bus-bars the power is distributed to step-up transformers and is thence transmitted to the sub-stations. In the sub-station the power is again transformed to low voltage. Assuming further, that the total power developed by the system in case of a short-circuit between the bus-bars and one of the step-up transformers is 25 000 k.v.a., the generators would then deliver power directly to the point of trouble through the almost negligible resistance of the bus-bars. It is therefore necessary to provide at this point a circuit breaker which will handle the 25 000 k.v.a. If a short-circuit were to occur at one of the remote sub-stations, although it is fed by this same 25 000 k.v.a. source, it has to receive its energy through the resistance of the long line and is further reduced due to the choking effect of

the transformers. The energy delivered is therefore very much reduced, depending on the characteristics of line and transformers and a circuit breaker installed at this point could be of a correspondingly smaller ultimate breaking capacity. H. G. MACD.

302—ELECTROLYTIC RECTIFIER FOR CHARGING TELEPHONE BATTERY —Would you consider it advisable to use electrolytic cells to obtain direct-current for charging telephone batteries in a small private branch exchange from an alternating-current source when the expense precludes the possibility of using other rectifying apparatus? C. R. F.

If the initial cost were the only expense to be taken into consideration, an electrolytic rectifier outfit would doubtless give satisfactory results. However, as the operating efficiency is low and the cost of renewal of the aluminum cell is considerable, the maintenance cost would probably be found to be quite high. The higher initial cost of a mercury rectifier outfit, for example, for the purpose desired would probably soon be counterbalanced by the higher operating efficiency, the lower maintenance cost and the improved continuity of operation. L. W. C.

303—AUTO - TRANSFORMER CURRENTS —Is the current of the secondary of an auto-transformer local with the tapped coils or does it flow back with the primary exciting current? K. B. S.

In an auto-transformer, the current in the tapped coils is the algebraic sum of the exciting current and the secondary current. Taking the case
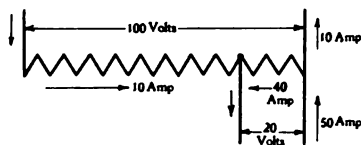
FIG. 303 (a)

shown in Fig. 303 (a), there would be 10 amperes flowing in one direction and 50 amperes in the opposite direction or a resultant of 40 amperes in the tapped coils. See also No. 6 in the JOURNAL for January, 1908.
I. E. C.

304—Directions for Calibration and Installation of Integrating Wattmeters — I am very desirous of obtaining literature explaining the principles of calibration and installation of integrating watt-meters; such information as will be of use to one connected with the meter department of a power company of considerable size having some 1 500 meters. It is necessary to keep these meters in repair, making such calibrations, adjustments, and repairs as required in the shortest possible time and without an elaborate layout of laboratory equipment. There is available for this purpose a bank of lamps and a portable integrating watt-meter. How is the formulae $W=(R \div T) \times C$ to be handled when the constant C is not given? A. E.

The simplest and easiest method of testing integrating service wattmeters is by the use of a portable integrating meter. The portable meter is connected with its current coil in series with the current coil of the service meter and its potential coil connected to the line at the same points as the potential coil of the service meter. The current coil of the portable meter should be of approximately the same capacity as that of the service meter. A load equal to approximately normal full load is then put on the meters and the number of revolutions of the portable meter is noted for a given number of revolutions of the service meter. This number should be taken large enough to continue the test over a period of at least one minute. In comparing some service meters with a portable meter, it is not necessary to reduce the number of revolutions to watt-hours because of the fact that the speed of the meters should be exactly the same, viz., 25 revolutions per minute at full load. If the number of revolutions of the standard meter amounts to exactly 25 for 25 revolutions of the service meter, the latter is correct; if the number of revolutions varies from 25, the percent registration is found by dividing the number of revolu-

tions of the service meter by the number of revolutions of the portable meter. For example, if the portable meter gives 24.3 revolutions in the time that the service meter gives 25, the percent registration is $25 \div 24.3$ or 102.9. This means that the service meter is 2.9 percent fast. It can be slowed down by adjustment of the permanent magnets. A second test is now made in the same manner on light load—generally about five percent load. If it is found that the service meter does not run correctly on light load, it should be adjusted to do so, the light load adjustment being effected in various ways in different meters. On alternating-current meters the light load adjustment ordinarily consists in varying the position of a conductor located at one side of the shunt field. In direct-current meters a compensating voltage coil is provided; this may be moved so as to produce a field through the revolving armature, and shifting the position of this coil gives the adjustment required. The revolutions of both standard and service meters can be reduced to watt-hours by means of the formula referred to in the question, after which the registration of the two meters may be compared. This is not necessary, however, as the comparison is made most easily by direct comparison of the actual number of revolutions of the standard and the number it should give for 100 percent registration of the service meter. Dividing the latter by the former gives the percentage registration of the service meter. The constant is given as watt-hours per revolution of the disc; hence, by multiplying the number of revolutions R of the meter made in a given time T by the constant C, the total watt-hours registered are obtained. On some makes of meters the constant is not placed on the disc because the speed of all sizes of meters is the same, say, 25 r.p.m. on full load. In an installation of service meters the following general rules should be borne in mind: The meter should be located on a substantial support free from vibrations (should never be mounted on a partition subject to jars such as those resulting from the slamming of doors, etc. It should be mounted at such height that it will be accessi-

ble for reading. It should be located in a dry place (free from damp walls or damp atmosphere); it should be mounted in a level position so that the shaft on which the disc is hung is in a vertical position, as carelessness in this connection is liable to introduce increased friction loss in the meter. See the article on "Integrating Wattmeters" by Mr. H. Miller, in the JOURNAL for October, 1907, p. 584. A. W. C.

305—STARTING SYNCHRONOUS MACHINES WITHOUT THE USE OF STARTING MOTOR—Please explain a method of operation and give a diagram of connections used in starting a synchronous motor or rotary converter from the alternating-current side without the use of a starting motor. M. S. H.

Self-starting synchronous motors are usually provided with a so-called squirrel-cage winding in order to in-
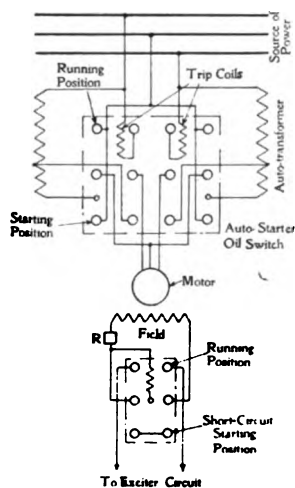
FIG. 305 (a)

crease the starting torque. The motor is first started on a reduced voltage obtained by means of auto-transformers, or taps brought out from the windings of the main transformers. The field is short-circuited during starting. When the motor reaches full speed on this voltage, which should be little less than the synchronous speed, it is switched to the

full voltage and the field excitation thrown on. The load may then be applied. The field switching may be accomplished by means of a two-pole, double-throw, field discharge switch or a combination of switches. The diagram Fig. 305 (a) shows usual connections for a three-phase synchronous motor started by means of auto-transformers and an auto-starter switch. See also, "Self-Starting Synchronous Motors" by Jens Bache-Wiig, in the JOURNAL for June, 1909, p. 347. C. H. S.

306—STARTING ROTARY CONVERTER— A 1 000 kw rotary converter and the alternating-current generator from which it received its power were started together from rest, the circuit connecting the two machines being closed before starting. The armature of the rotary oscillated and ratcheted forward, but did not revolve. The field, which was excited to about normal running value, was then broken and the armature started to revolve. The field was immediately closed again when the armature locked in step with the generator and speeded up as the frequency increased. (a)—What happened during the period of oscillation; at the instant of opening the field circuit, and when it was again closed? (b)—Assuming the frequency to be very low, would the machine have stopped if the field circuit had been closed at the wrong instant? (c)—What would have resulted if the field circuit had been left open at the beginning? (d)—If it had been closed as for self-excitation? (e)—Which method is the surest with a load connected to the rotary when starting? (f)—With the rotary started light? (g)—With two or more rotaries connected to the direct-current bus-bars to which the load is connected? G. F.

(a)—This oscillation may be explained in the following manner: In general the generator and rotary converter cannot start together from standstill, due to the fact that a sufficient voltage must be generated to

send the required starting current through the windings of the generator and rotary and their connecting leads, which necessarily have a certain amount of resistance. This means that possibly two or three percent of the normal voltage of the machine must be generated before the required starting current can be forced through the rotary converter armature and this, in turn, means that the generator must be running at two to three percent of its full load speed and generating current at a frequency of two to three percent of its full-speed frequency before the rotary converter even starts. The polyphase currents from the generator at this low frequency set up a rotating field in the armature winding of the rotary converter, traveling at two to three percent of the normal speed of the rotary. In order to attain synchronism it is necessary for the armature of the rotary to catch up in speed with this field. If the fields of the rotary are excited by direct-current, they will have a definite polarity. If, for instance, a north pole set up by the polyphase armature current is approaching a south pole of the rotary converter field, the armature will tend to start and accelerate towards synchronous speed. If, on account of the inertia of the armature, it does not reach synchronous speed by the time the armature pole has shifted past the field pole, then the field pole excites a retarding action on the armature and the armature core tends to slow down again. The accelerating action is repeated as unlike poles again approach each other. In this way an oscillation or vibration will be set up. If the armature had less inertia it could follow more readily and might reach synchronism before the armature pole passed the field pole, and would then continue to run properly. If it were possible to over-magnetize the generator field sufficiently to obtain the required voltage and starting current at a much lower frequency, then the rotary might slip into step with little or no vibration. If the field excitation in the rotary converter is cut off, the rotating field set up in the armature windings will then act on any secondary circuits in the field structure, the same as in any induction motor. The armature

will therefore tend to pull up to synchronism, or extremely close to it —so close that when the direct-current field is applied it at once pulls the armature into step with the generator frequency. This induction motor action is present, to some extent, even when the field of the rotary is excited at standstill, and this action might be so strong in some cases that weakening the field of the rotary, instead of opening it, would be sufficient to allow the induction motor action to preponderate so that the rotary would slip into synchronism. (b)—They might or might not have stopped under this condition. (c)—The induction motor action would have caused the armature to accelerate as in (a). (d)—Self-excitation would induce alternating polarity in the fields of the rotary. The oscillating action discussed in (a) is possible only with direct-current separate excitation; in starting, therefore, the action would have been similar to that in (c). (e) and (g) are not probable cases, as it is not good practice to attempt to start a rotary with the switches on the direct-current side closed and would be allowable only under unusual conditions of operation, in which case there would be a liability of difficulty in getting the armatures to accelerate sufficiently for synchronizing.

B. G. L. and E. R. S.

307—Meaning of Symbols Used in Connection Diagrams—Please explain the significance of the "x" mark shown on the receptacles indicated in the diagrams, Figs. 3 and 4, in article on "Meter and Relay Connections" in the Journal for May, 1909, p. 301.   P. H. W.

This nomenclature indicates that the receptacle connections are so arranged that the circuit bearing the "x" mark is closed when the plug is not in the receptacle, and open when the plug is inserted, thereby changing the direction of the circuit through the receptacle. In a four-point receptacle such as that indicated, the plug serves to bridge across from each lower contact to the contact shown directly above. This nomenclature has been used in connection with the diagrams appearing in various preceeding installments of the

series on "Meter and Relay Connections."

308—Starting Induction Motor on Full Voltage—In a case of emergency, could a 20-hp squirrel-cage induction motor be started on full voltage? C. R. F.

This would not be objectionable if not too frequently practiced and if the motor were started without load. The only source of danger involved is that the heavy currents resulting from throwing such a motor directly across the line tend to pull the ends of the coils out of place through the excessive magnetic attraction and repulsion between the conductors.

A. M. D.

309—Preliminary Design of Power Distribution System — There is under consideration the lighting of a town of about 1 000 inhabitants, between 700 and 800 sixteen-candle-power lamps being required. Either a steam or a gas producer plant would have to be used as a source of power.

(a) Would you suggest a two-wire 110-volt system or a three-wire 220/110-volt system?

(b) Which is cheaper as regards first cost and operating expenses, a steam plant or one with gas producer and gas engine?

(c) Please give approximate initial cost of such a system or otherwise a method of obtaining this and the operating cost, amount of coal used, etc.

(d) What would have to be the approximate charge for current necessary to make this a paying proposition (flat rate for sixteen-cadle-power lamp)?

K. B.

(a) A three-wire, 220/110-volt system, using a three-wire generator would effect a saving in cost of power for the distribution circuits.

(b) A small gas engine plant of about 60 kw capacity would cost somewhat less than twice that of an equivalent simple non-condensing steam plant. For equal power output, the cost of coal for the gas plant is about $1/4$ to $1/5$ of that for the steam plant, with average conditions.

(c) A 60-kw gas plant (without

foundation or building) costs from $125.00 to $140.00 per kw, and a corresponding steam plant costs about $70.00 to $85.00 per kw. The gas plant will generate a kw-hr on two to four lbs. of coal, while a corresponding steam plant requires 8 to 12 lbs. per kw-hr. See Bulletin No. 7 on "Gas Engines and Producers for Central Stations"—a paper presented by Mr. Robt. T. Lozier before the National Electric Light Association, Washington, D. C., June 4 to 7, 1907. It may be noted also that at the Atlantic City Convention of the N. E. L. A. held in June, 1909, a report was made by the Gas Power Committee upon the design and operation of gas producer apparatus of recent development.

(d) Rough estimates are of little value. Valuable suggestions might be obtained by reference to the schedule of rates published by the N. E. L. A. or by reference to the reports of various State Commissions (Mass., Wis., N. Y., etc.). To properly determine the rate the following must be considered: Cost of investment (i. e., interest on investment, depreciation, etc.), fuel, labor, load-factor, supplies, etc. E. D. D.

310—Design of Coil for De-Magnetizing Watches—Referring to Question No. 218 in the February, '09 issue, please give the dimensions, size of wire, and number of turns of a coil to be used on a 115-volt, alternating-current circuit for de-magnetizing watches.

A simple and effective alternating-current magnet can be constructed with the following specifications: For the core, use iron wire of any convenient size, e. g., No. 20 (the smaller the better, within reasonable limits). This wire should be cut to a length of about $3\frac{3}{4}$ inches and a sufficient number should be used to give a diameter of core of about $2\frac{1}{2}$ inches. A spool may be constructed using fibre washers for the end pieces, mounted on a sheath made of sheet brass, leaving a slot in the sheath the length of the spool to prevent serious eddy current loss therein. The spool should be covered with ample insulating material; shellaced or varnished paper, or thin sheets of mica cemented together with shellac or thin

tough paper may be used for this purpose. Upon this insulated core should be wound about 675 turns of No. 17 double cotton-covered copper wire. This design is suitable for use on a 110/115-volt, 60-cycle alternating-current circuit. It will be found convenient to have the coil so constructed that it will stand in a vertical position; the upper end being arranged to give a concave surface upon which a piece of felt may be glued in order to prevent scratching or otherwise injuring the watches. The method of de-magnetizing which should be followed is given in No. 218.   H. M. S.

311—EFFECT OF GROUND ON TRANS-MISSION LINES — (a) — What method is used in grounding low tension secondaries for delta and Y-connected transformers? (b)—Can they be directly grounded and lose no power? (c)—Is it possible to so insulate a 2 200-volt line that there will be no flow of current in case one of the lines should become grounded? (d) —Will all the current that flows from a high-tension line to the ground when short-circuited get back again to the other line and so on to the step-up transformers?   K. B. S.

(a)—With Y-connected transformers the middle point is grounded by connecting with a water pipe or to an iron rod or pipe driven about four feet into the ground. The standard specifications for making a permanent ground are given in an article on "The Protection of Electric Circuits from Lightning and Similar Disturbances" by Mr. R. P. Jackson, in the JOURNAL for April, 1908, pp. 225-6. It is not considered good practice to ground a delta system. It is sometimes done, however, by connecting the middle of the winding of one of the transformers to ground. (b)—With transformers grounded by direct connection, there is a very small charging current which will cause practically no loss of power. (c)—With an ungrounded system there would be no flow of current should only one of the line wires become grounded. There would be an extra voltage strain on the transformer, which might cause a break-

down. With a grounded system, however, there would be a severe short-circuit should one of the line wires be grounded resulting, of course, in an excessive flow of current. The use of a safety spark-gap is sometimes practicable. This is explained on pp. 229-30 of the above article. (d)—A short-circuit on the high tension line, whether through ground or otherwise, will cause a flow of current, all of which must flow through the step-up transformers.   I. E. C.

312—HEAT VALUE OF COMMERCIAL GRADES OF COAL—Please compare, from point of fuel economy, average Hocking run-of-mine costing on the firing floor, $2.25 per ton, with the average West Va. Splint run-of-mine, costing $2.50 per ton, used under the following conditions: 0.2 inch to 0.4 inch draft and hand firing on fixed grates with sudden changes in demand for steam due to a high peak load and possible sudden failures of the gas engine units during this peak.
                                F. G.

The comparative calorific values of the two grades of coal and the ash constituent can be obtained from the government reports prepared by the United States Geological Survey. This should determine their respective values as regards economy. For emergency conditions such as those cited in the question, the matter resolves itself into one of suitable grates to accommodate the high rate of combustion of the cheaper coal on peak loads. If the grate area is not ample, it might be necessary to use the higher grade of coal to sustain the maximum load, or else, to install stokers.   E. D. D.

NOTE •

Referring to No. 270, in the June, '09, issue, the exponent of the factor *10* in both formulas is positive and not negative as might be inferred. In the second formula, in which $B =$ total flux $\div$ area of core, A, the latter should appear in the divisor, thus: 4.44 fNA.

Motor Speed Variation   In the present and several preceding numbers of the JOURNAL, Mr. Specht has discussed various methods for changing the speed of polyphase induction motors. The methods which he discusses may be put into three general classes, namely:—

Two or more motors in tandem or cascade.

Two or more pole combinations on one motor.

Change in the supply frequency or its equivalent in change in the secondary frequency.

The induction motor is essentially a constant speed machine and is equivalent in general to a shunt-wound, direct-current motor with constant field strength. A comparison between the alternating-current induction motor and the direct-current shunt motor, as regards speed adjustment and regulation, can be made as follows:—

1—Rheostatic Regulation—The direct-current shunt motor with a rheostat in its armature circuit acts the same as an alternating-current motor with a rheostat in its secondary circuit. Both have maximum speeds corresponding to the rheostat all out. In both the speed will change, with change in torque, when resistance is in circuit, the only constant speed condition with change in torque being with the resistance cut out.

2—Alternating-current Tandem Operation—This corresponds to two or more direct-current shunt motors with their armatures connected in series. If both armatures are wound for equal speeds, then the tandem or series connections give half speed, as with the alternating-current motor. If one direct-current armature is wound for a higher speed than the other, which corresponds to two alternating-current motors with different numbers of poles, then four speeds may be obtained corresponding to the windings connected cumulatively, differentially and to each motor used separately. This corresponds to the four speeds of the alternating-current combination where two motors have different numbers of poles and are connected in tandem to give speeds corresponding to the sum or difference of the number of poles or are operated separately.

3—Change in Number of Poles—In the direct-current motor

this is equivalent to using an armature with two separate windings and commutators. If both windings have equal turns, or generate equal counter e.m.f's., then the two in series will give half speed, while each one alone will give full speed. If the windings are unequal, then each one alone will have its own particular speed, and this arrangement corresponds to the alternating-current motor with two different numbers of poles. Also, the two unequal windings could be connected in series, either cumulatively or differentially, to obtain two other speeds. This corresponds to a special method of internal tandem connection which could be used in alternating-current multi-speed motors when the arrangement of the windings will allow it without undue complication.

On the direct-current motor it would be difficult in practice to use more than two windings on one armature, corresponding to two pole-combinations in the alternating-current motor. However, in the latter it is practicable to obtain more than two combinations, in a number of cases, without undue complication.

4—Adjustable Speed Over a Wide Range—In the direct-current shunt motor the speed can be varied up or down over any desired range by varying the voltage supplied to the armature and any speed thus obtained is constant with changes in torque, provided the supply voltage is held constant at any given value. The field strength must remain constant, however, with change in armature voltage. In the alternating-current motor a similar result is obtained by varying the supply frequency and supply voltage in proportion. In this case the motor field strength remains constant, while the speed varies directly as the frequency. With the same current supplied to the motor the same torque can be developed at all frequencies and therefore at all speeds, just as in the direct-current motor with constant field strength and with varying armature supply voltage.

However, there is another method of adjusting the speed of the direct-current motor which seems to have no equivalent on the polyphase motor, namely, that in which the supply voltage is held constant, while the shunt field strength is varied over a wide range. In this one feature the shunt motor has a very great advantage over the polyphase induction motor for by this method fine gradations in speed may be accomplished in a very simple manner and the motor has essentially constant speed characteristics at all speeds. These speed characteristics can be obtained with the alternating-current motor by varying the supply frequency, as mentioned before, or by

an adjustable frequency machine in series with the secondary of the motor to be regulated. These arrangements, however, mean much additional apparatus and, for fine gradations in speed, an adjustable speed direct-current machine is preferable for operating the change-able frequency regulating devices.

If, however, the armature of a polyphase motor is equipped with a commutator and winding like a direct-current machine, it becomes possible to so construct the motor that the equivalent of a variable field shunt motor is obtained. This, however, takes us beyond the bounds of Mr. Specht's articles, and into a class of machines which cannot be termed simple induction motors.

These articles, and the foregoing comparisons, indicate that the polyphase induction motor is applicable where a limited number of definite speeds is required, and also where varying speed with change in torque is permissible. Where an indefinite or unlimited number of constant speeds is necessary, this type of motor in itself cannot meet the requirements. In such a case some auxiliary frequency changing appliance is required, which may be external to the motor to be regulated or may, in some designs, form part of the motor itself. Such devices, whether in the motor itself, or external to it, generally involve the use of a commutator, either in the primary or secondary circuit of the alternating-current motor, or in some part of the separate frequency changer.

B. G. LAMME

Notes from the Northwest   The Alaska-Yukon-Pacific Exposition is a success. I speak from the viewpoint of the visitor. The general plan and architectural design is pleasing and impressive. Trees and rich flower beds and grass plots abound. Buildings are admirably suited to their double purpose of presenting a harmonious appearance and offering suitable exhibit spaces. There is a general impression of fitness about it all. The buildings are of a uniform mild yellow or straw color, a happy contrast to the white glare of other fairs. There is substantial dignity with no endeavor to attempt the startling. It all impresses the untutored critic of the artistic and the beautiful, who is unable to analyze the effects, as well done and appropriate to its purpose.

The principal exhibits are those which relate to the wealth of the country. The forestry building—an exception in style and color, but so placed that it does not mar the symmetry of the main court—

is a magnificent structure of great logs, covered by their native bark. Within are gigantic specimens of forest wealth. The agricultural building is full of good things and shows how apples and potatoes have been permeated by the largeness of the Northwest. Mining is richly shown in its own building, and in the Alaska building with its exhibits of ore and nuggets and real gold bricks. The Government building is large and the exhibits are excellent; notably the aquariums. There is not much large machinery, and there is little electrical apparatus, except the General Electric Company's exhibit, which consist principally of small apparatus and includes an electrical kitchen.

The joint convention of the Northwestern Electric Light and Power Association and the Seattle section of the American Institute of Electrical Engineers was made up very largely of serious-minded central station men. They were earnest and practical and wanted to know more about the electrical and commercial problems incidental to their work. The papers were meaty and to the point and the discussions direct and worth while. The report of the Rate Committee was one of the best treated and most welcomed papers. The Seattle branch is thriving and energetic. It has permanent quarters, office room for its exclusive use and shares with other societies the Board of Commerce Auditorium.

I was fortunate in being in Portland and San Francisco on the evenings that the Institute branches were giving dinners to Secretary Pope. Portland, the youngest of the more than twenty sections, brought out about sixty men to meet the four visitors from the East, for in addition to the Secretary and Past-President, there was Mr. Lincoln, Chairman of the Sections Committee, who said it was his duty to get the Board of Directors to do what the sections wanted, and Mr. Gale, who brought greetings and good reports from the Schenectady section. The San Francisco reception was a double header. The section officers gave a dinner one evening and the section members a second one the next evening.

I spent an hour or two at the Cascade Tunnel, a hundred miles East of Seattle, on the Great Northern, and had a ride on the electric locomotive. I understand that Dr. Hutchinson is soon to present a paper on the electrical and operating features of this installation. The impressive fact is not so much that an electric locomotive can pull a train, but to realize the changes it has brought about.

The tunnel is about two and one-half miles long and has a grade of about two percent. Heretofore, the second steam locomotive in a double header has not been able to do much because the first locomotive used the air. Long freight trains were divided into as many as four sections which were taken through one at a time. Each trip of the locomotive back and forth must await the clearing of the tunnel of its smoke and gases, which is a slow process when the wind is not favorable. It has taken from about one to four hours to get a freight train through the tunnel by steam; it takes twenty minutes by electricity.

Two modest looking "iron boxes" were connected at the head of our ten car Pullman train with its two big steam locomotives. We moved forward up to the two percent grade on a reverse curve and entered the tunnel. To the front was a little star, a bright spot equivalent to one-sixty-fourth of an inch at a foot distance. It was the sky seen through the eastern portal of the tunnel. We glided on through the dry, clean tunnel, and for a long time the star was not perceptibly larger. Then we emerged and ran a little way and stopped. The electric locomotives were withdrawn and the train coasted away down the eastern slope. The electrics then took a complete freight train of 60 cars up the grade back into the tunnel. Just inside the grade changed and there was an alarming tendency to go West. Not a brake was set, but the motors recuperated, holding back the train and sending the surplus power to a rheostat at the power house, 30 miles away. If the railway managers pass the same verdict as do the engineers and firemen, the day of tunnel electrifications is imminent. CHAS. F. SCOTT

The Design of Low Pressure Turbine Installations The engineering considerations surrounding the installation of low pressure turbines have more interesting phases than anything else in modern steam turbine work. This applies rather to the methods of operating the turbine than to the design of the turbine itself, for a low pressure turbine is about the simplest piece of apparatus imaginable. Its design is, indeed, a much simpler matter than the standard turbine because, first, there is but half the heat drop to be considered and hence but half the number of rows of blades is required; second, as the volumes of steam for a given power are so very much greater than in a standard turbine, good, substantial blade dimensions are readily obtained, further permitting the turbine to be designed for

operation at comparatively low speeds, even though the simple double-flow principle of design be employed.

The interesting and, indeed, the difficult features of low pressure turbine engineering, lie in determining the most desirable method of installation and the conditions under which the turbine shall be operated. For instance, shall the turbine be connected to the exhaust of the reciprocating engines without the intervention of any governing apparatus, and if so, what is the best receiver pressure between the reciprocating engine and the turbine?

If a governor is employed, shall it control a valve on the inlet to the turbine or shall it control a valve in an exhaust pipe going directly from the reciprocating engine exhaust to the condenser?

Shall a regenerator be employed, and if so, for how long a period shall the regenerator be required to supply enough steam for the turbine to carry full-load?

Further, to what extent may live steam be utilized which would otherwise blow out through the safety valves in the case of an intermittently operating reciprocating engine? In rolling mills, for instance, it is not customary to cease firing because the rolling mill is stopped for a few minutes.

To what extent may a motor-generator set or a rotary converter be employed to tie together direct-current reciprocating engine units and alternating-current low pressure units, or vice versa?

Should the low pressure turbine generator in any case be synchronous or non-synchronous?

The above questions give an idea of the variety of methods. While the article on "The Low Pressure Turbine" by Mr. E. D. Dreyfus, in the current issue, in a measure treats superficially on various phases, it treats in detail only one phase of the work, viz., that of applying a low pressure turbine without a governor to a reciprocating engine unit, the turbine and reciprocating engine unit furnishing power to the same bus-bars. Hence as the load rises and falls, the receiver pressure between the reciprocating engine and the turbine will rise and fall. The article shows how the Corliss engine is affected by the low pressure turbine and clearly exhibits the methods generally used for determining what is the preferable division of load between the respective units and what is the best receiver pressure to select.

FRANCIS HODGKINSON

THE RATIONAL SELECTION OF ALTERNATING-CURRENT GENERATORS

F. D. NEWBURY

THERE are certain inherent characteristics of any piece of apparatus and certain conditions of operation that must be properly adjusted to each other if the apparatus is to operate satisfactorily. This fact while obvious and universally admitted is not by any means universally applied. It has naturally been applied first where the penalties of neglect have been greatest. Thus very early in the days of electric railways the necessity of a proper method of selection of motor equipments became apparent, and several satisfactory methods have been worked out and are now in general use. Six years ago a motor for industrial work was sold simply as a motor, without particular reference to the machine or load it was to drive. To-day, with the greater appreciation of the flexibility of motor drive, an industrial motor and its control apparatus must be selected with a full knowledge of the work to be performed. The appreciation of these facts has led to methods of motor selection as rational and as satisfactory as in the case of railway motors.

What has already been accomplished in the case of railway and industrial motors is just beginning to be done with alternating-current generators. By calling attention, in the present article, to the more important characteristics of the alternator, it is hoped that some impetus may be given to this movement.

There are certain operating characteristics of the generator that are vital, others that may be desirable but are not so important. Thus, it is vital that normal voltage be maintained, while it is not essential that the efficiency be a certain percentage nor that the voltage regulation be a certain amount. It may be desirable that the efficiency be good, but it is not a matter of "operation or no operation." The most important points concerning a generator are its ability to hold up voltage, its ability to operate at a safe temperature and its ability to operate without exceeding safe mechanical stresses, yet these vital matters are sometimes lost sight of in a microscopic examination of efficiencies and regulation. It is not to be understood

that these latter characteristics should be forgotten; they should be considered but in proper perspective.

In a discussion of alternating-current generator operation there is one thing that cannot be given too much emphasis; this is the effect of power-factor, particularly its effect on the maintenance of normal voltage and on safe temperature.

With varying load and all other conditions constant, the terminal voltage of an alternating-current generator will fall as the load increases, due to three causes: 1—Armature resistance. 2—Armature self-induction. 3—The demagnetizing effect of the armature current on the field.

The drop in voltage due to armature resistance is well known and requires no explanation beyond the statement that it is in phase with the armature current.

The drop in voltage due to armature self-induction is a similar effect except that it is 90 degrees out of phase with the armature current, since it is caused by the magnetic field set up around the armature conductors by the armature current. The resistance and inductive drops are not peculiar to alternating-current generators, but occur in all circuits carrying alternating current.

The demagnetizing effect of the armature current is an effect due to the reaction of the magnetic field set up by the armature winding upon the magnetic field set up by the field winding. When a generator is carrying load, the magnetic field generating voltage is the resultant of the main exciting field and the armature field. The demagnetizing effect of the armature current causes a reduction in the magnetic flux which in turn causes a reduction in generated voltage, assuming constant field current. With the usual operating condition of constant terminal voltage the effect of armature resistance and self-induction is to make necessary an increase in generated voltage with increased load, while the demagnetizing effect necessitates only an increase in field magnetic flux to make up for the reduction in flux due to the armature current. The latter does not require any increase in the general voltage since the action is confined to the magnetic flux.

In ordinary generators the resistance drop will vary between

0.5 and four percent of the terminal voltage; the drop due to self-induction will vary between five and 15 percent, while the drop due to demagnetization may be anything from 25 to 50 percent. These figures are comparative numerical values of the three factors without reference to their actual phase relation. At 100 percent power-factor this phase relation is such that the resistance drop is in phase opposition to the terminal voltage and is wholly effective in reducing the terminal voltage while the two other factors are 90 degrees out of phase, and so have relatively little effect. Since the resistance drop is so small, the total effect at 100 percent power-factor is small, as shown by Fig. 1.

With a load at zero power-factor on the generator the phase relations are exactly reversed, the resistance drop is 90 degrees out of phase with the terminal voltage and has a negligible effect, while the inductive drop and demagnetization drop are in phase opposition to the terminal voltage and have their maximum effect. The reduction in voltage at zero power-factor is therefore considerable on account of the large values of these two factors, as shown in Fig. 2.

Table I gives the inductive component and, therefore, the demagnetizing component for different power-factors.

TABLE I

Total k.v.a. Load.	Power-Factor or Energy Component of Load	Wattless Component of Load
100 percent	100 percent	.0 percent
100 "	99 "	14 "
100 "	98 "	20 "
100 "	95 "	31.2 "
100 "	90 "	43.4 "
100 "	80 "	60 "
100 "	70 "	71.4 "
100 "	60 "	80 "
100 "	50 "	86.6 "
100 "	30 "	95.4 "
100 "	0 "	100 "

As it is the wattless or inductive component of the current which acts directly in demagnetizing the field, the table shows directly the effect of different power-factors in reducing the voltage. It may be seen that the inductive component increases rapidly with

the first few percent departure from 100 percent power-factor, but less rapidly for further reductions, the effect of reducing the power-factor from 100 percent to 98 percent being approximately as serious in its effect in reducing the terminal voltage as reducing from 98 to 90 percent.

In actual operation the terminal voltage is not allowed to fall, but with increase in load or decrease in power-factor the field current is increased so as to increase the resultant field flux and maintain the terminal voltage constant. The small reduction in terminal voltage that occurs at 100 percent power-factor as the load is increased necessitates only a small increase in field current to maintain constant terminal voltage; while the large reduction in terminal voltage, which occurs at low power-factor with increasing load, necessitates a large increase in field current to maintain constant terminal voltage. A low power-factor, therefore, means a greatly increased field current over that required at high power-factor, even for the same armature current. This increased field current requires a correspondingly higher exciting voltage across the field terminals, and results in a large increase in field coil temperature.

FIG. 1   FIG 2

$TD =$ Total generated voltage (equal in both cases). $OR =$ Resistance drop. $RI =$ Inductive drop. $ID =$ Demagnetization. $OT =$ Terminal voltage. $OX =$ Drop in terminal voltage with load.

The capacity of a given generator will, therefore, vary inversely with the power-factor; that is, the lower the power-factor the larger the generator required. With a given energy load the k.v.a. capacity of the generator must be greater with lower power-factor and the operating conditions for the larger generator are more severe on account of the larger field current required. Should the available exciter voltage be insufficient to force the required field current through the field winding, the generator terminal voltage necessarily falls. It is no exaggeration to state that the majority of alternating-current generator troubles are due to the failure of the generator to "hold up voltage" on account of the inability of the exciter to furnish the largely increased field current required by loads of low power-factor. This feature of the operation of generators cannot be too carefully watched.

CHARACTERISTIC CURVES OF ALTERNATING-CURRENT GENERATORS

In Fig. 3 typical characteristic curves are given which illustrate the foregoing statements regarding the effect of power-factor and from which can be determined the safe operating limits of a generator. The curves give the following information:—

a—Nominal rating at 100 percent power-factor.

    1—Regulation at all k.v.a. loads.

    2—Efficiency at all k.v.a. loads.

    3—Temperatures at all k.v.a. loads at 100 percent power-factor
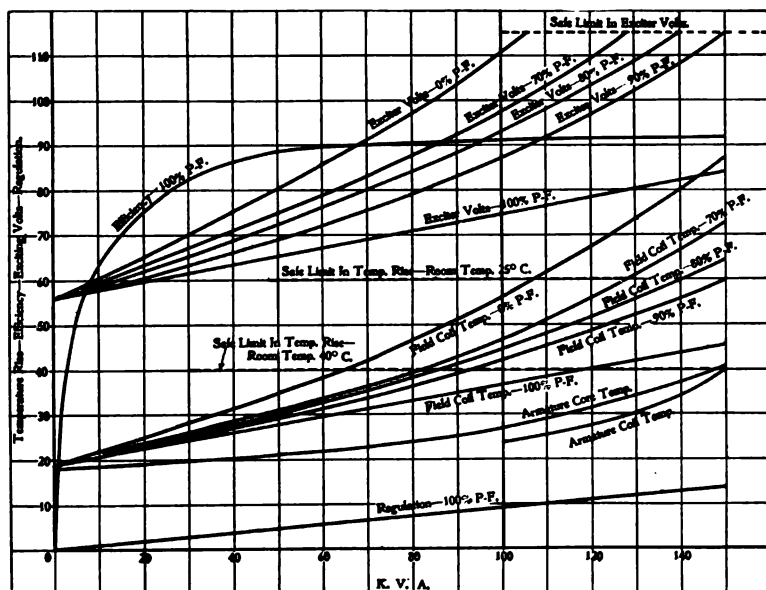
FIG. 3—CHARACTERISTIC CURVES OF ALTERNATING-CURRENT GENERATOR

with separate curves for the temperature of the armature core, armature coils and field coils.

    b—Service rating at operating power-factors.

    1—Temperatures at all k.v.a. loads at 90, 80, 70 and 0 percent power-factors with separate curves for the field coil temperatures. The two curves given for armature coil and armature core temperature are applicable for all power-factors in the generator covered by the curves. As a matter of fact there is a small increase of temperature in these parts due to the transference of heat from the field coils and increased core loss with decrease in power-factor,

but this increase is so small that only one curve for each has been drawn, this curve representing the worst condition. In generators of different proportions, where this may not be true, separate curves would have to be given.

2—Exciter volts required *at the generator collector rings* for all k.v.a. loads at 90, 80 and 70 and 0 percent power-factors. The 0 percent power-factor curves do not represent an operating condition for a generator, but are given as a convenient reference line to show the worst condition as far as power-factor affects operation.

3—Three limit lines are given, one for exciter volts, on the basis of a 125-volt exciter, and two for temperature rise for room temperatures of 25 and 40 degrees C.

In order to understand the performance curves, it is necessary to understand the features of operation that impose a limit on the output of the generator. In explaining this, two classes of load will be considered—first, a steady load such as an industrial load of small induction motors, a central station load or the load on large systems, whether railway, lighting or transmission; and second, a fluctuating load such as a load of welding machines, large motors or, in general, any load in which the load units are comparable in size with the generator.

With a steady load the maximum load that can be carried by the generator will be determined by one or more of the following limits:—

1—Available exciting voltage; evidenced by the ability of the generator to maintain normal voltage.

2—Temperature rise; evidenced by heating of the insulation and consequent grounding or short-circuiting of the windings.

3—Bearings and strength of parts transmitting the torque; evidenced by heating of the bearings, vibration or actual breakage.

The curves give all the necessary information for defining the limits from causes *1* and *2*. It is only necessary to make sure that at the desired load and power-factor the curves for exciter volts and temperature rise are below the safe limit line. It will be noted that the limit line for exciter volts is 115 volts. This allows 10 volts drop in voltage between the exciter and generator collector rings. In many cases this allowance is necessary, but in some cases when it is known that the drop between the exciter and generator is sufficiently small, the limit line may be raised to 120 volts.

It will also be noted that widely different limit lines are given for allowable temperature rise, depending on the room temperature.

The temperature rise limit is determined by the actual temperature as measured by the thermometer, i. e., by the temperature rise added to the room temperature. Therefore, as the room temperature is increased the safe temperature rise limit must be equally reduced. In addition, the safe limit with higher room temperature is further lowered by the fact that with higher room temperature the observed temperature rise is increased due to the higher initial resistance of the windings and the reduced density of the cooling air.*

The proper temperature rise limit can be selected from a knowledge of the probable room temperature at the place the generator is to be installed.

The necessary information for defining the limits of rating for the third cause, strength of parts, cannot be conveniently shown on the curves as plotted on a k.v.a. basis. With the exception of belt-driven generators, the limit, as far as strength of parts is concerned, is fixed by other conditions than the load. In direct-driven or engine type generators the load on the bearings is not increased with increase in load and the shaft when sufficiently large to be rigid is amply large to transmit any required torque. In belted generators the load on the bearings does increase with the output, on account of the belt pull, so that this may become a limit. However, the belt pull is a maximum at 100 percent power-factor and decreases as the power-factor decreases, so that at operating power-factors the limit to rating is invariably imposed by electrical rather than mechanical factors.

It is worthy of note that nothing has been said regarding inherent regulation as a limit in rating for steady loads. This is of very little importance with steady loads since in many cases the change in load is so slow and over so small a range that the voltage can be maintained constant by hand adjustment of the field rheostat. Where this is not adequate the regulation can always be taken care of by an automatic regulator, such as the Tirrill regulator. Moreover, by sacrifice in the relatively unimportant characteristic of inherent regulation, more important gains can be secured in the maintainance of voltage under overloads and low power-factor and in efficiency.

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*This is provided for in the Standardization Rules of the A. I. E. E. by reducing the observed temperature rise one-half of one percent for each degree of room temperature above 25 degrees C. This lowers the safe temperature limit from 45 to 40 degrees in round numbers, as indicated on the curve.

The effect of power-factor on regulation is of considerable importance in determining the operating consequence of regulation. The relation between power-factor and regulation is shown by the curve, Fig. 4. It will be noticed that the regulation percentage rapidly increases as the power-factor decreases, this following directly from the relation between demagnetizing effect and power-factor as given in Table I. While the regulation percentage may be six or ten percent at 100 percent power-factor it will be 13 or 20 percent at 90 percent power-factor, and 17 or 24 percent at 70 percent power-factor. It should be noted that the curves given in Fig. 4 are necessarily approximate since the relation between power-factor and regulation is dependent on the relative values of the several factors causing drop in voltage and on the degree of saturation. The curves are, however, based on average proportions.
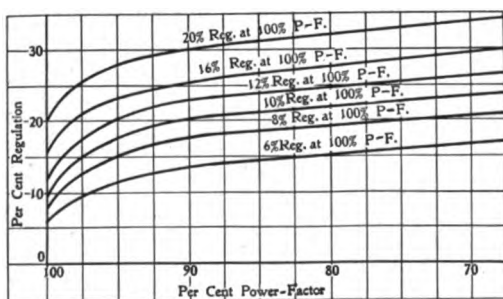
With loads of the second class, that is, fluctuating loads, the same limits to output apply as with steady loads. In addition to these, voltage regulation may become a limit. In all cases where the load is fluctuating an automatic regulator should be installed except when the fluctuations occur infrequently and the operator can correct them by hand regulation. A typical case of this kind is a station having one large motor which is started once or twice a day at known times. In some cases the conditions are so severe that an automatic regulator does not operate quickly enough to maintain the necessary voltage. It is then necessary to provide a generator of exceptionally strong field compared with the armature, and to provide a regulator in addition. A load of this kind is a welding load with a power-factor of 50 to 60 percent where the instantaneous changes in load are equal to the total capacity of the generator.

In general, with fluctuating loads, more attention must be paid to voltage regulation in the selection of the generator than with steady loads. Loads of welding transformers, squirrel cage induction motors or synchronous motors, where the load unit is more

FIG. 4—CURVES SHOWING RELATION BETWEEN POWER-FACTOR AND REGULATION

than 50 percent of the generator normal rating, are liable to give trouble if the generator is not properly selected for such load conditions.

DETERMINATION OF THE CHARACTER OF THE LOAD

If a generator is to be properly selected it is necessary to determine the following characteristics of the load:—

1—The maximum k.v.a. load that the generator will be called upon to carry.

2—The nature of the variation of the load, i. e., whether steady or fluctuating. This can be expressed, first, by the ratio of the "units, of the load" to the generator capacity, that is, the ratio of the rating of all motors, transformers or other load units to the generator ratings, and second, by the frequency with which each load unit is connected to and disconnected from the generator circuit.

3—The power-factor of the load. This characteristic of the load is equally as important as the size of the load in k.v.a. It should be recognized that an alternating-current generator rating in k.v.a. or kw without the operating power-factor is just as incomplete as a rating would be that gave the power-factor and omitted the k.v.a. or kw. The probable operating power-factor in a new plant is undoubtedly difficult to determine, yet its importance is so great that this difficulty should be no reason for not making a careful and intelligent attempt to secure this information.

The power-factor of a load will depend not only on the kind of apparatus, transformers, motors, etc., but on the ratio of the actual load on the apparatus to the rating of the apparatus. A tabular statement should be made of each unit of load and the proportion of its actual load to its rated load, together with the power-factor, and, in the case of motors, the efficiency. From these the total load in k.v.a. and the power-factor of the total load can be derived from the following formulae:—

Kw of the system = sum of the kilowatts required by the different loads.

Wattless component for each load $= \dfrac{\text{kw input } \sqrt{(1-P^2)}}{P}$,

where P = power-factor of the load.

Wattless component for system = sum of the wattless components for each load.

Total k.v.a. for system $= \sqrt{(\text{total kw})^2 + (\text{total wattless component})^2}$

Power-factor for system $= \dfrac{\text{Total kw}}{\text{Total k.v.a.}}$

When definite information is not available on the characteris-

tics of any of the component loads, it is well to assume the lowest probable ratio of operating load to rated load. This is especially true in the case of industrial installations where the connected load is made up almost entirely of induction motors, as such plants frequently operate at a very low ratio of actual to rated load, with a correspondingly low power-factor.

The method of determining the resultant load and power-factor on a system is illustrated by the following numerical example:—

Assume a load consisting of:
1 000 incandescent lights, 56 watts each.
50 arc lights, 500 watts each.
One 50 horse-power cage-wound induction motor, operating at full-load.
One 50 horse-power cage-wound induction motor, operating at one-half load.
Three 50 horse-power cage-wound induction motors, operating at three-fourths load.

TABLE II

Load	No. Units	Ratio Operating Load to Rated Load		Efficiency	Kw Input	P-F. %	Wattless Component
Inc. Lamps	1000	100 percent	Normal		56	90	27.3
Arc Lamps	50	100 "	"		25	70	25.4
Motors....	1	100 "	"	87.5 percent	42.7	89.5	21.3
Motors....	1	50 "	"	87 "	21.4	78	17.2
Motors....	3	75 "	"	88 "	125.4	86	75.5
Total...					270.5		166.7

Total load on generator in k.v.a.$=\sqrt{270.5^2 + 166.7^2} = 316$ k.v.a.

Power-factor of total load $= \dfrac{\text{Total kw}}{\text{Total k.v.a.}} = \dfrac{270.5}{316} = .85.$

SELECTION OF GENERATOR FOR ITS PRIME MOVER

It is important that the information concerning the character of the load be obtained, not only for its bearing on the selection of the generator, but also for its bearing on the selection of the prime mover in relation to the generator. When the maximum k.v.a. load and the operating power-factor have been determined the equivalent kilowatts may be obtained by multiplying the k.v.a. by the power-factor. This divided by the generator efficiency will give the maximum energy required from the prime mover. Then a prime mover should be selected having this same maximum capacity. It should

be noted that this requires that the overload rating of the prime mover be known. In other words, the engine or water wheel and the generator should be compared on the basis of maximum energy capacity and not on normal capacity, either energy or k.v.a.

To select the prime mover and generator on the basis of normal 100 percent power-factor rating always results in an engine or water wheel too large for the generator. A generator can be dangerously overloaded, or fail to hold up voltage, while the engine is operating at partial load and poor economy, and the purchaser has uselessly increased his investment charges.

As an example of the proper method of comparison, assume a generator having a normal rating of 100 k.v.a. at 100 percent power-factor; assume that the operating power-factor of the generator load will be 70 percent and the maximum capacity of the 100 k.v.a. generator at this operating power-factor 125 k.v.a. or 87.5 kilowatts; assume the efficiency of the generator under these conditions to be 88 percent. The maximum output of the prime mover should then be 100 kilowatts, or 134 horse-power. With a steam engine having 25 percent continuous overload capacity the normal rating of the prime mover should be $\frac{100}{125}$ 134 or 107 horse-power. With a gas engine or water wheel having only ten percent continuous overload capacity the normal rating of the prime mover should be 122 horse-power. The actual size of the prime mover selected will of course be governed by the available standard sizes of units.

METHOD OF RATING

The rating of an alternating-current generator should include not only a nominal comparative rating in order that the generator may be compared with other generators, but it should give a "true" rating in order that the generator may be compared with the service it is expected to perform. And the generator should not be selected in accordance with the nominal rating as, unfortunately, it is in the majority of cases, but in accordance with the "true" rating based on actual service conditions.

The nominal rating should be considered simply as a "measuring stick" and it is only necessary that different manufacturers use the same "stick." This requirement, however, implies a simple basis of rating so that different manufacturers can be brought into agreement. For a satisfactory true or service rating the one essential requirement is that it shall be based on the actual service condi-

tions, so that both rating and service may be expressed in the same terms and may be accurately compared. The problem, then, of establishing a service rating is to determine the service conditions that limit the output.

A familiar illustration of these facts is afforded by the well-established practice in rating railway motors, already referred to. The motor is given a nominal or comparative horse-power rating based on a one-hour shop test, and in addition is given a "real" continuous rating based on the actual service conditions. This real rating, in one method of rating, is expressed in terms of the k.v.a. input represented by the maximum current the motor will carry continuously with a safe temperature and the "equivalent" service voltage, determined by the kind of service. The nominal one-hour rating is of little value in judging what a railway motor will do in driving a certain car on a certain schedule and on a certain track. These actual service conditions, however, can be reduced to a current of known heating effect and a definite equivalent voltage. The "real" rating of the motor is also expressed in these same terms and by means of this real rating the motor and the service can be directly and accurately compared. The motor is not selected in accordance with the nominal rating, although such was the case in the early days of electric railroading. It is selected in accordance with the real rating based on actual service conditions. To put the matter briefly, the nominal one-hour rating is for the purpose of comparing the motor with other motors and the real rating is for the purpose of comparing the motor with the service it is expected to perform. It is worth noting that the nominal rating fulfills its comparative purpose only indifferently—it does not even give a complete comparison. It is, in fact, merely a relic of the first crude method of rating and is perpetuated simply because, at the present time, there is no other method used in common by a majority of the motor builders.

A method of rating has recently been adopted by one of the large electrical manufacturing companies complying with the above requirements of a rational and complete rating. In effect two ratings are given. One is based on normal loads and overloads at 100 percent power-factor, in line with the usual practice at the present time. This is the comparative rating. The performance data in this comparative rating includes temperatures at normal load and overload, and efficiencies at normal load and partial loads. All of this data is given at 100 percent power-factor, since it can be given more

easily at this power-factor and since 100 percent power-factor is used by practically all manufacturing companies as the basis for the rating of alternating-current generators. The second rating is the service rating at the operating power-factor. The performance data in the service rating consists of the maximum continuous k.v.a. capacity at the operating power-factor and 60 degrees C. rise either in the field or armature, and the equivalent kilowatts. The exciter rating in kilowatts and voltage is also a part of the service rating since the exciter rating specified corresponds with the service rating of the generator. In connection with the service rating, the dependence of the maximum capacity on room temperature is pointed out.

In the service rating one load only is given, which is the limiting load at the operating power-factor, as shown in the characteristic curves, instead of following the more usual practice of giving a so-called normal load with 25 percent or 50 percent overloads. The reasons for adopting this form of service rating are as follows:—

The one limiting rating gives all the necessary information for determining the ability of a generator to operate satisfactorily under specified service conditions. Temperature is of no operating consequence unless it is above the safe point, and if it is below this point it is of no consequence how far below it is. There is, therefore, no reason for giving, in the service rating, temperature guarantees for loads below the maximum load the generator can safely carry; in fact, no more reason than there is for a manufacturer of bushel baskets to guarantee that his bushel baskets will safely hold half a bushel. The same reasoning holds good for strengths of shaft, bearings and other parts; for the ability of the generator to hold up voltage and for any feature that limits satisfactory operation.

What is needed more than anything else is knowledge as to how much load the generator will safely carry. It seems more sensible to determine this fact directly, as is done in the method of rating described, than indirectly, as is done when a "normal" rating and certain overload ratings are given.

In this method of rating, the service rating is a continuous rating rather than a rating for a limited time. The reason for this is that, in the great majority of generators, in fact, in practically all generators except those of large size and small number of poles, as large a rating at operating power-factors can be given for con-

tinuous operation as for any shorter time. This is due to the fact that the rating at low power-factor is determined by the ability of the generator to hold up normal voltage as well as by temperature rise, and to the fact that in generators of modern design, which are very well ventilated, the generator reaches its final temperature with a certain load within a relatively short time. An additional reason for giving a continuous rating is the advantage of basing all temperature guarantees on the same condition. At the best, the predetermination of temperature rises is difficult and with all guarantees on a continuous basis, they can be estimated somewhat more accurately.

It may seem that the preceding reasoning should apply equally well to the 50 percent overload guarantees at 100 percent power-factor in the comparative rating which is given for one hour. At 100 percent power-factor, however, the ability to hold up voltage is not a limit to rating even at 50 percent overload. In belted generators the bearings are not usually designed for 50 percent energy overload continuously, so that the limits to rating imposed by temperature and by the bearings allow a better guarantee to be made at 100 percent power-factor for one hour than would be possible continuously.

Many of the specifications now issued for generators of large capacity call for but a single rating at 50 or 60 degrees C. rise in continuous operation, and it is probable that eventually this simple method of rating, beginning to be used for the larger units, will be extended to the smaller ones and the nominal comparative rating at 100 percent power-factor will be entirely discarded.

THE LOW PRESSURE TURBINE

COMBINED WITH THE STEAM ENGINE

EDWIN D. DREYFUS

THE adaptation of the low pressure turbine to commercial requirements has resulted in a very interesting and valuable development; namely, the use of low pressure turbines taking steam from the exhaust of steam engines. By this means additional output may be obtained without increase of boiler capacity and without discarding present steam engine equipments. A number of articles on the general subject of low pressure turbines have already appeared in this magazine and in other technical periodicals, giving the underlying theories and possibilities of the low pressure turbine along with the results of actual tests. Supplementing the above discussions, the present article gives a study of the application of the low pressure turbine under certain definite conditions, in which is shown a method of determining the relation between the various elements considered which will give the most satisfactory power plant operation.

Owing to the various conditions under which steam engines operate in practice, each low pressure turbine installation usually possesses different engineering features. The primary consideration will depend upon whether the exhaust steam supply for the turbine is intermittent or continuous. Cases of intermittent supply include rolling mills, hoisting and reversing engines and steam hammers, in which the use of the regenerator principle may be involved, governors with auxiliary live steam admission valves or a combination of the regenerator and the auxiliary live steam valve. Careful consideration must be given in all cases to the time element of supply and demand, to determine which system will be most effective under the conditions of service encountered.

A simple case of non-intermittent supply will be found where non-condensing or condensing engines are exhausting into a common header (or can be so arranged) and ample steam is always available for the turbine supply. For this class of work, a pressure relief valve (as ordinarily used in condensing systems) is employed to prevent excessive back pressures.

If a turbo-generator is connected to the common bus-bars with the main engine units a governor is not essential. The turbine out-

put will then vary with the steam delivered to it by the engine of engines. Any plant having a number of non-condensing engines located sufficiently close together so as not to make their interconnecting piping too expensive, offers a favorable opportunity for the use of a low pressure turbine to secure increased power.

COMBINED ENGINE AND TURBINE UNIT

The problem which will often confront the owners or operators of first-class reciprocating engine plants, will be how to extend their plant: 1—Whether by duplicating the present type of units; 2—Purchasing complete expansion turbines, or 3—By installing low
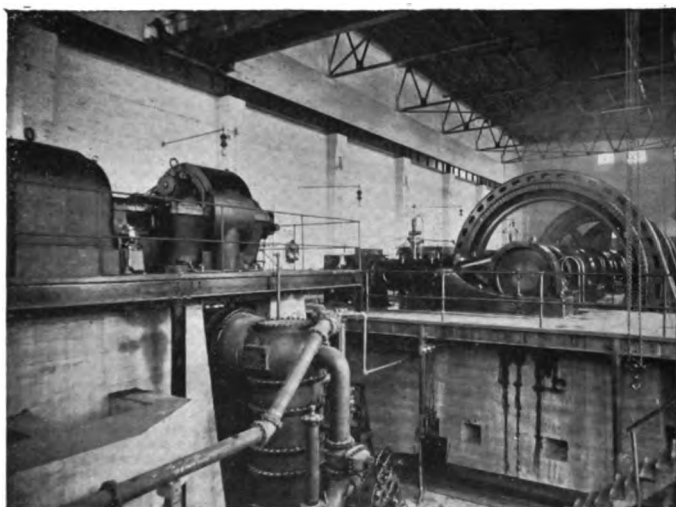
POWER PLANT CONTAINING THREE 750 KW GENERATORS DIRECT-CON-
NECTED TO RECIPROCATING COMPOUND ENGINES WITH I 000 KW
LOW PRESSURE TURBINE-GENERATOR SET OPERATING ON ENGINE
EXHAUST, AND CONDENSER DIRECTLY BENEATH TURBINE.

pressure turbines to operate on the exhaust from the existing steam engines. This leads to a consideration of the characteristics of the two types of machines in order to determine the combination which will be most effective in increasing capacity and improving operating efficiency. To illustrate the advantages obtainable by the use of an engine and low pressure turbine combination, a definite problem of power extension will be analyzed.

ENGINE ECONOMY

It will be assumed that in the station in question there are a

number of cross-compound Corliss condensing engines of 1 000 kilowatt capacity eoch; and that the load demand on the station has increased so as to require a plant having double the capacity and the increased output is to be secured by installing low pressure turbines. The initial steam pressure is assumed to be 150 pounds gauge and a vacuum of 26 inches (30 inch bar.) is to be maintained at the exhaust nozzle; the cylinder proportions being approximately one to four. Larger cylinder ratio is favored only in cases where practically constant power work obtains, as in textile mills and similar industries. But for fluctuating loads, as in electric railway operation, industrial power plants etc., ratios of one to four, or lower, are preferred, as there is less valve pounding on variable loads. At normal load, a mean effective pressure of about 29 to 30 pounds (referred to the low pressure cylinder) for the above pressure and vacuum, would ordinarily be used for the most economical working. For twenty-five cycle railway work an engine speed of 94 r.p.m. for 1 000 kilowatts capacity would be required, and with a 48-inch stroke, the piston speed would be 752 feet per minute. A low pressure cylinder 54 inches in diameter would then be necessary to develop a normal rated output of 1 500 indicated horse-power at the above m.e.p. and piston speed. (If 60-cycle operation were considered, the speed would probably be 90 r.p.m. and piston speed 720 feet a minute.) For an approximate ratio of four to one, a 28-inch high pressure cylinder would be employed, as it will conform with regular commercial patterns and sizes, the true cylinder ratio being in this case 3¾ to 1.

An average compound Corliss engine maintained in good condition, should deliver an indicated horse-power with a steam consumption of 13.25 pounds per hour at its most economical rating and under the above operating conditions. This engine, running non-condensing, would consume practically 19 pounds per indicated hp-hr. With mechanical and electrical efficiencies of 93 and 95 percent respectively at normal load, the steam consumption per kilowatt-hour output condensing, amounts to 20 pounds and non-condensing, 28.8 pounds. The total water line curves for varying back pressure, may now be constructed, using standard engine economies for different operating conditions. In Fig. 1, the heavy line *D* represents condensing operation, and line *B* non-condensing with back pressures slightly above atmosphere (16 pounds absolute). The light lines show the total hourly water consumption at different loads for intermediate exhaust pressures and also for back pressures exceeding atmosphere.

From these water lines, the output of the engine for a given flow of steam may be determined for any exhaust pressure. For example, when passing 25 000 pounds per hour the delivered output with 16 pounds back pressure is 820 kilowatts; with 10 pounds, 1 000 kilowatts, and with two pounds, (or approximately 26 inches vacuum) 1 230 kilowatts.

LOW PRESSURE TURBINE ECONOMY

In a low pressure turbine designed to operate with an inlet pressure of 15 pounds absolute, and to exhaust into a vacuum of
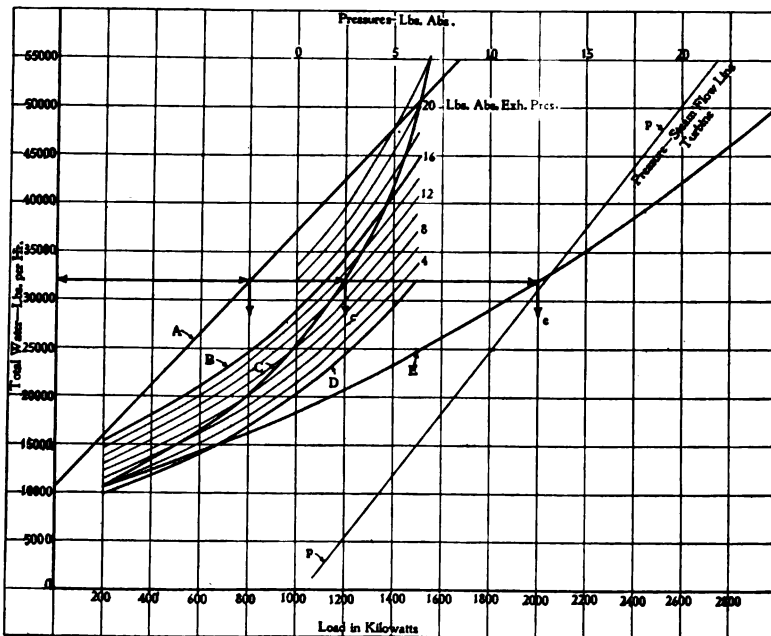
FIG. 1—CURVES SHOWING ENGINE AND TURBINE AND COMBINED WATER RATES
28″ and 54″ by 48″ compound Corliss engine and low pressure turbine. *A*—Low pressure turbine, 28″ vacuum. *B*—Engine non-condensing. *C*—Engine with resultant back pressure. *D*—Engine condensing, 26″ vacuum. *E*—Engine and low pressure turbine combined, 28″ vacuum.

28 inches (referred to 30-inch bar.) the water rate will be approximately 23.6 pounds per brake hp-hr, or 33 to 34 pounds per kilowatt-hour. As there will probably be from seven to ten percent moisture in the steam at the engine exhaust, only 90 to 93 percent of the steam from the engine will be available for the low pressure turbine. A suitable steam separator placed between the engine and turbine is recommended in most installations to remove the water

of condensation, as the effect of water is to increase the water consumption of the turbine by a percentage double the amount of moisture present. The approximate economies of a 1 500 brake horsepower low pressure turbine and the effect of varying vacua are clearly shown in Fig. 2. A change of approximately five percent in economy takes place for each inch difference in vacuum at full-load. This value, however, varies for different designs. Incidentally, an improvement in the engine performance ensues, as for the same output the turbine inlet pressure decreases with an increase
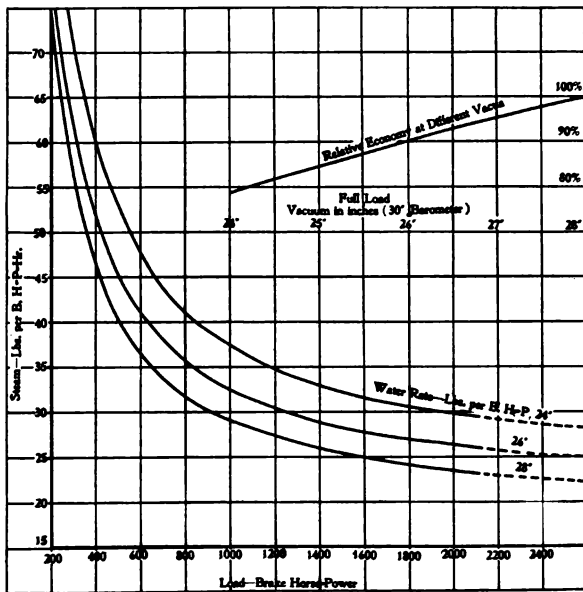
FIG. 2—ECONOMY TEST ON A 1 500 BRAKE HORSE-POWER
LOW PRESSURE TURBINE

Also relative economy at different vacua, speed 1 800 r.p.m.

in vacuum, hence reducing the back pressure on the engine correspondingly.

TURBINE CHARACTERISTICS

With the engine performances and low pressure turbine characteristics previously indicated, the results of combined operation can be closely approximated. In a turbine without a governor the load and quantity of steam flowing are proportional to the inlet pressures. In the case in hand, it was found by trial that a turbine capable of handling 40 000 pounds of moist steam (37 200 pounds

dry steam) at an engine exhaust pressure of 16 pounds absolute provided the best division of work at maximum load and best efficiency between 1 000 and 2 000 kilowatts load on the combined set. The capacity-pressure line in Fig. 1 is then drawn, showing the steam flow at various pressures, which furnishes a means of obtaining the resultant engine water line when the turbine is operated in conjunction with the engine. Considering the same steam flow in both machines, the back pressure on the engine must correspond to the turbine inlet pressure, due allowance being made for pressure drop (one to one and one-half pounds) and deduction for moisture. Then, on this basis, the resultant engine water rate curve C is obtained as shown in Fig. 1.

With the turbine designed to handle 37 200 pounds dry steam at 15 pounds inlet pressure at normal rating (allowing for drop between engine exhaust and turbine nozzle and, furthermore, accounting for seven percent moisture at exhaust), the low pressure turbine water line A is obtained. This line of total consumption per hour is practically straight, as in the high pressure turbine, the slope of the line being taken directly from the economy tests presented in Fig. 2.

By referring to the resultant engine water line C and turbine total consumption line A, the amount of work developed in each machine for equal steam flows may be determined. Summing up the kilowatt values of A and C for given steam flow, the combined water line E is obtained. On inspection of the total water lines A, C and E, the division of work between the two machines at different combined outputs may be readily noted. At 1 500 kilowatts combined load, the engine delivers 970 kilowatts and the turbine 530 kilowatts; at 2 000 kilowatt normal output of the combined set, the engine generates 1 200 kilowatts and the turbine 800 kilowatts or 33 1/3 percent less than the engine, as at c, a, e; and at 3 000 kilowatts, 50 percent overload on the combined set, the two machines divide work equally. Thus, the division of work for any given output can be obtained. In this particular case the work is equally divided between engine and turbine at maximum overload.

It may, however, be best under other conditions to have an equal division occur near normal rating. The relative distribution of work between the engine and turbine can be modified by changin the pressure-steam flow characteristics of the turbine by designing it to pass the same quantity of steam at a higher pressure. This would affect both the turbine water rate A and engine result-

ant *C*. Under these new conditions, the turbine would slightly improve in economy, due to being operated over an increased pressure range. Raising the back pressure on the engine correspondingly increases its consumption, which, being greater than the gain in the turbine, causes a falling off in the combined results. Under this condition, water lines *A* and *C* would come closer together, and the division of work would be less disproportionate at light loads. But the advantage in having a better distribution of work at fractional loads is materially offset by decreased economy of the combined set, and the possibility that when an indicator is used there will be found to be loops in the cards.

If a low pressure turbine of greater capacity at the same inlet pressure be employed, the overall results will be improved on overloads, due to the higher efficiency of the larger machine. On one-half load and less there will be increased steam consumption on account of relatively greater friction and condensation losses. The two machines would then have equal output much beyond 3 000 kilowatts combined load.

As the size of the low pressure turbine used with a given engine is increased (for instance, above the capacity selected), the effect will be to have the engine operating continuously on overloads for the normal rating of the combined unit. Hence, a rational decision as to the proper size of turbine to install, depends largely upon the unit loading factor, the engine cylinder ratio and maximum cut-off in the high pressure cylinder, and the insurance against air leakage between engine and turbine.

As a definite initial pressure is required to pass a given weight of steam, as is true in a low pressure engine cylinder with a fixed cut-off, the low pressure turbine may be regarded as the third cylinder of a triple expansion unit. However, the turbine expands the steam actually to the condenser pressure, whereby it derives its high efficiency, which is not the case with the low pressure cylinder unless of unreasonable proportions.

ENGINE CHARACTERISTICS

To insure satisfactory operation of the engine under all conditions of load and back pressure, the steam cycle in the two cylinders of the compound machine must be carefully studied. If the turbine is so small as to require at any load a higher inlet pressure than the terminal or release pressure of the engine when passing a given quantity of steam, the engine will then expand the steam

below the exhaust pressure, resulting in a loop in the indicator card and causing objectionable pounding of the exhaust valves.

An idea of the change in terminal pressure with load can be obtained from the theoretical expansion lines (dotted) in Fig. 3. At the earliest point of cut-off observed, the steam is expanded to about nine pounds. By using a back pressure of but seven pounds the looping is avoided. This diagram emphasizes how effectively the engine and turbine work together on variable back pressure. Fig. 4 shows the approximate engine terminal and turbine inlet pressures
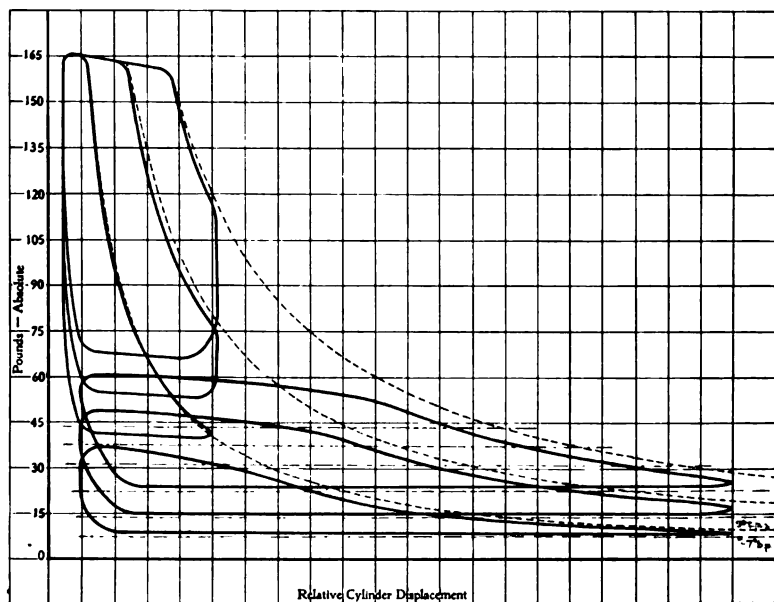
FIG. 3—COMBINED INDICATOR DIAGRAMS
Back pressure varying with load. - - - - Theoretical expansion curve.
— - — - — Receiver pressure. — — — Back pressure.

at different loads on the combined unit discussed. The dotted lines represent the probable back pressure at the engine exhaust nozzle with allowance made for friction drop between engine and turbine. If a constant back pressure of nine pounds had been maintained in this case, looping in the low pressure cylinder would have taken place at 1 200 kilowatt loads and under. It will be seen that at full load (2 000 kilowatts) there is a terminal drop of about six pounds.

Looping in the high and the low pressure cylinder cards is not only objectionable from a standpoint of quiet running, but it also represents negative work and reduced economy. In combining a tur-

bine and engine, the most serious case of trouble will be caused by expansion loops in either cylinder and over-compression in the low pressure cylinder. To give the proper conception of these conditions, the cards in Figs. 5 and 6 are shown. Most engine builders provide only a "comfortable" fit between the valve heads and the bore. And, as the valve bears on the lower half circle or less, there will be some free play above the valve, particularly so after several years of service. Then, when the pressures below the valve exceed the force above it (either from looping or over-compression), the valve will be lifted off its seat and "slam" on the return stroke. Ordinarily, compound non-condensing engines are designed for
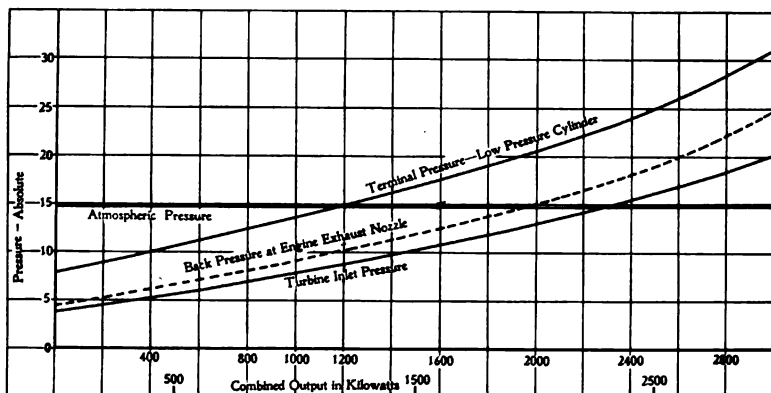
FIG. 4—ENGINE TERMINAL AND TURBINE INLET PRESSURES

At different combined loads, 1.5 lb. friction drop in interconnections at 2000 kw, other loads proportional.

from three to four pounds terminal drop in the low pressure cylinder at economical rating, and for about seven to eight pounds when compound condensing.

It has been demonstrated by numerous tests that the percentage of cylinder condensation varies with the point of cut-off; the earlier the cut-off, the greater the condensation, and vice-versa. Hence, the very early cut-off necessary to expand the steam to such back pressures that the entire expansive energy of the steam will be utilized is accompanied by excessive condensation losses. If then the cut-off be increased to a point where the work lost, by not expanding completely, equals the loss due to condensation, the best engine efficiency will be obtained. With the terminal drop as given in the above example, the efficiency ratio (actual water rate compared with the ideal water rate) of the engine is improved while

that of the turbine would not be noticeably affected. Appreciable terminal drop also proves beneficial to the engine from a mechanical point of view as previously mentioned and has many advocates among Corliss engine designers in this country.

Three principal methods of governing of compound Corliss engines are to be considered in order to insure both good operation and efficiency.

1—High pressure cut-off variable; low pressure fixed.

2—Parallel cut-off; both high and low pressure cut-off variable in the same direction, and cut-off advanced and reduced in both cylinders equally.

3—Parallel cut-off with the range of travel of the high pressure cylinder cut-off greater than the low pressure cylinder; that is, proportionately.

Most existing compound engines can be arranged for any of
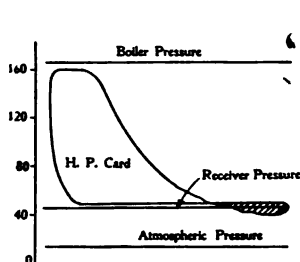
FIG. 5—INDICATOR CARD WITH EX- FIG. 6—INDICATOR CARD WITH COM-
PANSION LOOP   PRESSION LOOP
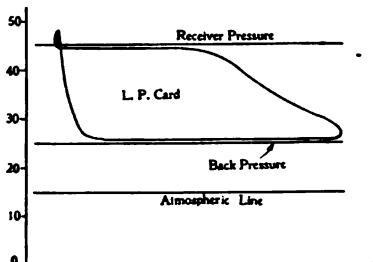
the above methods at small expense. With the parallel system, having equal cut-off in both cylinders, equalization of work at all loads is obtained when operating with constant steam conditions, that is, with constant initial and exhaust pressures. Also the receiver pressure remains practically constant. Under conditions of variable exhaust pressure, however, this does not hold, and it is necessary to have the receiver pressure rise with increased back pressure. If the low pressure valve gear be arranged so that the volume of the low pressure cylinders at earliest cut-off is greater than that of the high pressure cylinder, loops in the indicator card from the latter will always be avoided.

In preventing over-compression in the low pressure cylinder on overloads, the point of compression and clearance must be figured. The amount of compression in a given cylinder may be readily computed. For example, with a clearance of five percent

and compression at 95 percent stroke, the volume of steam will be reduced one-half, and inversely, the pressure doubled. Thus, if the back pressure were 20 pounds the pressure at the end of compression would be 40 pounds for these conditions. As to the latest point in the return stroke at which it would be desirable to set compression, it may be closely estimated from the weight of the reciprocating parts and fixed according to the conditions of the pins and bearings. With good working surfaces on the crosshead and crank pin bearings and liberal lubrication, the compression might be reduced and the bearings taken up to prevent pounding. This is quite feasible in most double-acting engines. Therefore, with clearance and point of exhaust valve closure known, compression pressures for increased load and back pressure may be obtained, and the maximum travel of the low pressure valve gear limited to maintain the receiver pressure above any high compression in the low pressure cylinder. Such methods have been actually tried out in practice. Practically equal work can be developed in the two cylinders over a wide range of load without expansion loops or overcompression. That better regulation and mechanical performance obtains when the two cylinders practically divide work, is generally conceded. This will be found especially true where the inertia of the fly-wheel is not sufficient to insure satisfactory parallel operation when there is a wide disparity of work between the two cylinders. Furthermore, in case of a cross-compound engine, it may happen that the crosshead and crank pins are not liberal enough in dimensions for one side to sustain the major portion of the work on overloads. Where possible, the low pressure cut-off should be placed under the control of the governor to avoid time lag in the low pressure cylinder. This will give better results where close regulation is necessary.

IMPROVED ECONOMY

An improvement of from 20 to 25 percent in steam economy is obtained by combining the low pressure turbine with a compound condensing engine of normal cylinder proportions, and from 40 to 45 percent with the same engine non-condensing (this may be applied in a general way where the proper non-condensing ratio is used). Considering a single cylinder Corliss engine in connection with a low pressure turbine, the coal bill per unit of power developed could be decreased from 50 to 60 percent. It will be noted

that the most economical water rates for the compound Corliss engines which have been used in this analysis are extremely good—20 pounds per kilowatt-hour condensing and 28.8 pounds non-condensing; and for the simple engine, 35 pounds per kilowatt-hour. These engine economies are, in fact, better than generally obtained in most power plants in which improper valve adjustment and leakage will ordinarily be found. Therefore, the improvement which has been indicated as possible in the average reciprocating engine power plants, should be conservative.

With the combination of the low pressure turbine as the third
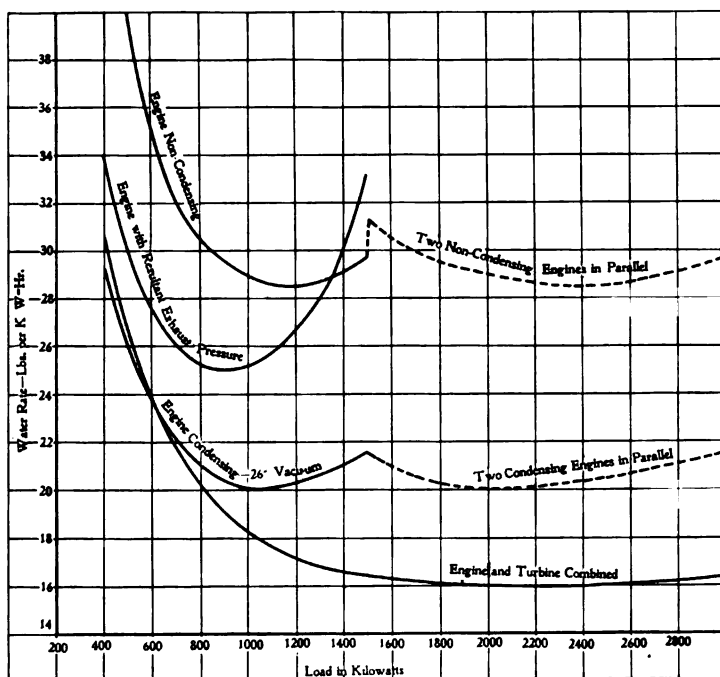
FIG. 7—COMPARATIVE WATER RATE CURVES

cylinder of the compound condensing engine, the normal rated capacity of this complete unit would be increased from 1 000 to 2 000 kilowatts. Comparative water rate curves, derived from the total water lines in Fig. 1, are given in Fig. 7.

For a comparison of economies, suppose duplicate engines had been installed in place of the low pressure turbine, then the water rate of two such engines operating in parallel for a load of 2 000 kilowatts may be represented by extending the water rate curve

for a single engine, as shown in dotted lines, Fig. 7, for condensing and non-condensing. Thus, making 2 000 kilowatts the normal station load, the improvement in economy for various loads may be observed and are shown in the lower half of Fig. 8 expressed in percent of engine consumption.

Referring to the water lines, Fig. 1, the increase in capacity obtained by the addition of a low pressure turbine over condensing
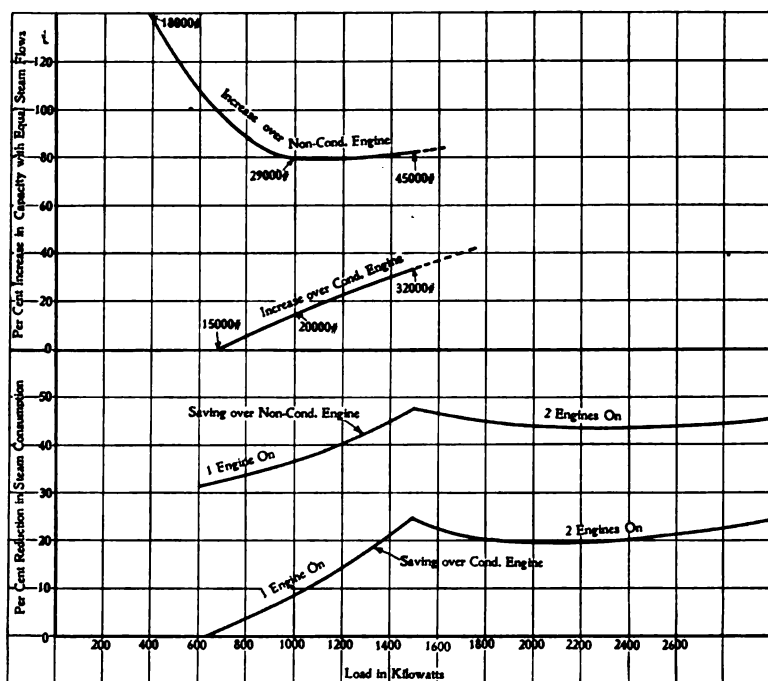
FIG. 8—CURVES SHOWING PERCENTAGE GAIN IN ECONOMY AND CAPACITY

and non-condensing operation above may be readily noted. For example, when passing 20 000 pounds of steam, condensing, the engine develops 1 000 kilowatts and when exhausting into a low pressure turbine with the same steam flow, the combined output is 1 145 kilowatts or 14.5 percent greater work. Passing 32 000 pounds of steam, an output of 1 500 kilowatts condensing becomes 2 000 kilowatts combined, or 33.5 percent gain. Similarly, the increase in capacity over non-condensing operation may be obtained (see upper half of Fig. 8), being a minimum of 80 percent at rating.

In order to obtain increased capacity with a low pressure turbine, the engine high pressure cylinder must be equipped with double eccentrics, or else the design must permit of the addition of a second eccentric if only one has been provided.   Thus the cut-off may be increased from about 45 percent to 75 percent to carry the overloads on the combined set.

GENERAL REMARKS

In considering the installation of a low pressure turbine in connection with an existing steam engine plant, the features which should be given attention are as follows:

1—Initial pressure (gauge) at throttle.   Quality of steam.

2—Engine cylinder dimensions—diameter and stroke.

3—Revolutions per minute.

4—Single or double eccentrics on high pressure cylinder.   If not, can high pressure cylinder be provided with double eccentrics?

5—If direct-connected, normal rated capacity of generators.

6—Approximate fly-wheel weight and diameter.

7—Low pressure cut-off; a—Control by governor; b—Fixed; c—Variable by hand.

8—Probable location of turbine with respect to engine.

9—General description of the engine, particularly regarding low pressure rod packing, crank and crosshead pin dimensions.

10—Size of engine exhaust nozzle.

11—Available condensing water, quantity and temperature.

12—Nature of load.

13—Percent clearance, high and low pressure cylinders.

14—Engine indicator cards at various loads.

SPEED CONTROL OF INDUCTION MOTORS BY FREQUENCY CHANGERS

H. C. SPECHT

I N addition to the principles and the applications of different means of accomplishing speed variation of induction motors considered in two recent articles*, mention was made of methods of variation of speed by change of frequency. This can be accomplished, for practical applications, in several ways, somewhat similar in regard to the apparatus involved, but differing in the relative sizes of the respective machines required in the set and in their suitability to given applications. These methods are based upon either of two general principles. By the *first principle* speed variation is obtained by changing the primary frequency applied to the driving motor and operating it as an ordinary induction motor. The *second principle* is that of connecting the primary winding of the driving motor to the power circuit of constant frequency, speed control being obtained by impressing different frequencies upon the secondary winding of the driving motor.

According to the first principle, it would be necessary to change the terminal voltage in the same ratio as the frequency, if constant torque at constant current (i. e., increase of horse-power output with increase of frequency) is required. If the voltage on the primary is kept constant, the torque decreases in proportion to increase of frequency, the horse-power output, therefore, remaining constant for the same current.

In the application of the second principle, in which the primary is connected to a line of constant frequency, and a varying frequency is impressed on the secondary, the action is as follows: Assuming that the current in the secondary of the motor produces a rotating field which progresses in the same direction as the field induced by the primary, a speed corresponding to the difference of the primary and secondary frequencies is obtained. If the secondary field rotates in the opposite direction from that of the primary, then the resultant speed will correspond to the sum of the two frequencies. By the method of supplying to the secondary a variable frequency and to

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* See the JOURNAL for July and August, 1909, pp. 421 and 492 respectively.

the primary a constant frequency, the characteristics and action of the motor become similar to those of a synchronous motor. The motor must run at speeds corresponding to the sum or difference, as the case may be, of the respective primary and secondary frequencies. Therefore, if a drop in speed with increase of load is required in order that "peak" loads may be carried by the flywheel action of rotating parts, the frequency changer should possess characteristics such that, with variations of load, the frequency will be correspondingly increased or decreased. This latter principle is applicable only in cases where wide variations of load do not take place in short intervals as, otherwise, difficulty could be expected, due to the liability that the motor will fall out of step.

An example of the first principle is represented by the arrangement of induction motor and frequency changer set shown in Fig. 1, A being a direct-current motor and B an induction motor. The primary of the induction motor B is connected to the alternating-current line and the speed of the set is controlled by the direct-current motor A. The secondary of this motor B furnishes the power to the motor which is to be run at variable speeds. The frequency C and voltage E in the secondary of motor B are determined by the following formulas:
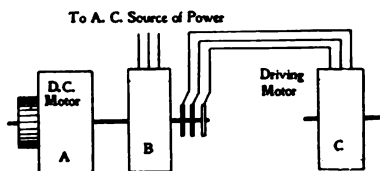
FIG. 1

$$C = C_1 \left[1 \pm \frac{N}{Ns} \right], \text{ and } E = E_1 \frac{t_2}{t_1} \left[1 \pm \frac{N}{Ns} \right]$$

in which C_1 = frequency of current in primary circuit.
E_1 = voltage of primary circuit.
N = r.p.m. of the frequency changer set.
Ns = synchronous r.p.m. of motor B.
t_2 = number of turns in the secondary winding of motor B.
t_1 = number of turns in the primary winding of motor B.

In these formulae the minus sign is to be used when the set is running in the normal direction of rotation of motor B (operating as a motor) and the plus sign is to be used when the set is running in the direction opposite to the normal rotation. It will be observed from the above formulae that the voltage changes in the same ratio as the frequency. Hence for the same current in the driving motor, constant torque will be obtained, i. e., the horse-power developed by the driving induction motor with a given value of current,

changes in the direct ratio of the frequency and, accordingly, in proportion to the speed. With the frequency changer set running in the normal direction of rotation of motor B, torque is furnished by motor B through the shaft to A, which becomes a generator, i. e., direct-current power is pumped back to the direct-current line. When the set is run in the direction opposite to the normal rotation of motor B, the direct-current machine A operates as a motor and delivers power to the shaft of the set. The power in motor A for either of the foregoing cases is, however, only a fraction of the power supplied to the driving motor C, its exact amount depending upon the maximum and minimum frequency, and power required for motor C. Therefore, motor A can be made relatively small in most cases. However, B must be practically the same size as the driving motor. Considering further the fact that the frequency changer set may be built for high speed, it is evident that the dimensions of the set will be relatively small and it generally will have a lower cost than other equipments designed to give corresponding speed variations. Especially, if motor C is a slow speed motor for variable speed, the cost of the frequency changer set will be only a fraction of the total cost.

Motor C can be a squirrel cage motor. If its load is very unsteady and equalizing of the load in the alternating-current supply circuit is desired, a fly-wheel may be added to the driving shaft of C and the speed characteristics of the direct-current motor A made such, that with increase of load, the speed of motor C drops sufficiently to enable the fly-wheel to assist it in carrying the peak loads.

The foregoing method can be applied with especial advantage in cases where the driving motor C cannot be located close to the source of power supply and the adjustments of speed of the driving motor are to be made at the power station; also, in cases where a direct-current driving motor is not desirable.

Another method of changing the frequency is by means of an arrangement similar to that just described, except that the induction motor B is operated as an induction generator. The frequency and voltage in the secondary of motor B are then,—

$$C = C_1 \left[1 - \frac{N}{Ns} \right] \text{ and } E = E_1 \frac{t_2}{t_1} \left[1 - \frac{N}{Ns} \right]$$

From the fact that the induction motor B has to act as an induction generator, it can readily be seen that the set always has to run above the synchronous speed of motor B. The advantage of this arrangement is that a leading current is obtained, thereby improving

the power-factor of the alternating-current supply circuit. However, it has the disadvantage that the direct-current motor A has to be of the same capacity as motor B, the latter being of the same capacity as in the previous case. Accordingly, this method of changing frequency has a limited application.

The methods given in the last example may also be used to impress a variable frequency on the secondary of the main or driving motor. A further method is to use an ordinary alternating-current generator with a small number of poles. The driving motor of this kind of frequency changer set would have to be again a direct-current motor. This kind of a frequency changer set is generably preferable to the foregoing method, as the size of the set can be made much smaller, the exact size depending on the speed ranges which are desired. For small ranges of speed the frequency and voltage of the alternating-current generator are low, i. e., a set of small capacity is required. On the other hand, this kind of set has the same advantage as the frequency changer used in connection with an induction motor, in that the voltage increases in the same ratio as the frequency. And further, it has also the advantage that, at the same time, it may be made to act as a compensator, the same as the induction motor when operated above synchronous speed. To obtain this compensating effect, however, the generator must be over-excited, that is, its voltage must be higher than the induced voltage in the winding of the main motor. In order that the main motor (driving) shall drop in speed with increase of load, to take care of peak loads by the fly-wheel action of the rotating parts, it will be necessary here, as in the previous case, that the frequency changer set possess the characteristic of increasing or decreasing the frequency with variation of load, depending on the relative directions of the primary and secondary rotating fields in the main motor.

It has been noted that, for the foregoing methods of changing frequency (or speed), sufficient direct-current power is required to make up for the change in frequency. As a rule, however, alternating-current and direct-current are not both available. If there were no other use for direct-current power, aside from its present application, it would not be advisable to put in a direct-current generating set. Therefore, as a third method of obtaining variable speed by change of frequency, the method shown diagrammatically in Fig. 2 may be more practicable. The primary of induction motor A is connected to the alternating-current supply circuit and its secondary

is connected to the primary of another induction motor, C, the latter also being a wound-rotor type of machine, mounted on a separate shaft. The secondary of motor C is connected with the armature winding of a rotary converter, B, mounted on a common shaft with the driving motor A. The commutator of B is in circuit with the armature of another machine, D, which is mounted on the same shaft as machine C. This latter machine acts as a frequency changer and its speed is governed by that of the direct-current machine D, which is given a certain excitation by a shunt field or by a compound shunt and series field, depending on the kind of speed regulation which is desired. The machines D and B may be self-excited or separately excited. For a certain speed of the set C-D, and with the connection between the commutators of B and D closed, the driving or power set A-B will have a definite speed. The regulation of speed

To A. C. Source of Power

Driving Shaft

A

Driving Motor

B

C

D

Frequency Changer Set
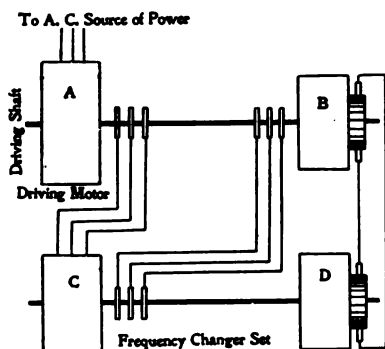
FIG. 2

is accomplished entirely by regulation of the field of the machine D, a single adjustment only being required for a given speed, without regard to the load.

For example, assume that the frequency of the line circuit is 50 cycles, that machine A has ten poles, that C has four poles and that B has six poles; also that the connection between the commutators of B and D is such that the rotating field in the secondary of C makes the machine C act as a motor. Finally, assume that the driving set runs at 200 r.p.m. This would mean that the frequency in the secondary of motor A is equal to 33 1/3 cycles, and the frequency in the armature of machine B is equal to 10 cycles, and by taking the difference of 33 1/3 and 10 cycles the speed of the set C-D is given as 700 r.p.m. For the above connection the speed range is between the limits of zero and the direct concatenated speed of A and B, $\left(=\frac{50 \times 120}{10 + 6}\right) = 375$. When the two leads between the commutators of B and D are reversed, the speed range of the set A-B will be between the direct concatenated speed, 375, and the synchronous speed of motor A operating as a single motor. In this case machine C acts as a generator and machine D as a motor. The

speeds and frequencies of the machines can be expressed by the following formulae:—

$$N_1 = \frac{(C_1 - C_2) \times 120}{P_1} \quad \text{or} \quad N_1 = \frac{C_3 \times 120}{P_3} \quad \dots\dots\dots (1)$$

Combining these;
$$\frac{C_1 - C_2}{P_1} = \frac{C_3}{P_2} \quad \text{or} \quad C_2 = C_1 - \frac{P_1}{P_4} \times C_3 \quad \dots\dots\dots (2)$$

$$N_2 = \frac{(C_2 \pm C_3) \times 120}{P_3}$$

Substituting the value of C_2, $N_2 = \left[C_1 - C_3 \left(\frac{P_1}{P_3} \pm 1 \right) \right] \times \frac{120}{P_3} \quad \dots\dots (3)$

In which: $C_1 =$ line frequency, $C_2 =$ frequency in the secondary of A and primary of machine C; $C_3 =$ frequency in the secondary of machine C and armature of B; $N_1 =$ r.p.m. of driving set A-B; $N_2 =$ r.p.m. of frequency change set; $P_1 =$ number of poles in A; $P_2 =$ number of poles in B; $P_3 =$ number of poles in C.

In formula (3) the plus sign is to be used when motor C is acting as a motor and the minus sign to be used when C acts as a generator. In the foregoing example the set would have the following speed limits: C-D, 900 to 1 125 r.p.m. when the driving set A-B is running from 600 to 375 r.p.m., in which case machine C is acting as a generator; 0 to 1 500 when the driving set is running from 375 to 0 r.p.m., in which case machine C is acting as a motor.

As previously mentioned, the speed regulation of the set C-D is accomplished by regulating the field of machine D. The field of machine B can be over-excited, in which case a leading current will be obtained on the alternating-current side, i. e., rotary converter B can be used at the same time as a compensator to raise the power-factor of the current. Accordingly, in cases where it is desirable to improve the power-factor of the line circuit, this method of changing speed proves doubly useful.

The starting of the sets can be accomplished in different ways. One way is to start motor A as a single motor with starting resistance in the secondary circuit. After the driving set is up to full speed, the connection between motors A and C may be closed. Then the proper field excitation can be given to D and B and synchronism in the auxiliary set will follow. Another way is to start the auxiliary set C-D first. This may be done by connecting the primary of motor C to the line, provided the voltage is suitable. After this set has reached full speed the primary of motor A is then connected to the line. The auxiliary set may also be started by connecting the primary of motor A directly to the line, at the same time having the commutators of B and D so connected that machine C will act as a motor and D as a generator. The fields of B and D are not to be

excited until the auxiliary set *C-D* has reached full speed. Then, in starting the driving set *A-B,* machine *B* receives power from *D* and *C,* and assists the acceleration of set *A-B*. With the increase in speed of set *A-B,* the auxiliary set *C-D* slows down, and all the kinetic energy due to fly-wheel effect in the auxiliary is converted into electrical power, driving machine *B*. By this method of starting a high starting torque can be obtained with lower current from the line.

The sizes of machines *B, C* and *D* depend on the speed limits, the amount of compensation and, of course, on the size of motor *A* ; in every case, however, they will be smaller than motor *A*.

In case several motors are to run at variable speeds, it might be much cheaper to use one large rotary converter or motor-generator set, the alternating-current power to be transformed into direct-current power and the direct-current motor used to drive the motors.

A motor-generator set driven by an induction motor is to be preferred in all cases where the load on the driving motors is changing very much and suddenly, because in such a case a synchronous motor or rotary converter may fall out of step.

Where the load conditions are not very severe in regard to sudden high peaks a rotary converter or motor-generator set with synchronous motor may be preferable, as it is possible with these machines to run with normal power-factor or even leading current.

In addition to the various electrical and mechanical schemes of obtaining multi-speed control of induction motors, mentioned in this and the two previous articles, there are many others which perhaps in a few special cases might be worth taking into consideration. Of all the present practicable arrangements that are available there is none which might be called ideal in every respect; each has some disadvantages. Some are rather complicated in their control and operation; some are less reliable than others, and practically every one has the main disadvantage of being rather expensive as compared with a single speed induction motor of the same capacity. It is, therefore, not surprising that, from time to time, new schemes continue to be brought forth.

THE CHOICE OF A CONDENSER (Cont.)

FRANCIS HODGKINSON

JET CONDENSERS

The essential differences between jet and surface condensers have been pointed out. There are, however, greater diversities in the various types of jet condensers than in surface condensers. Jet condensers may be classified as follows:

The Plain Jet Condenser—The plain jet condenser consists of a chamber containing a suitable supply nozzle, or the like, for admitting the injection water. In this chamber the steam is actually condensed. In conjunction with this is a pump handling both the air and the mixture of cooling water and condensed steam.
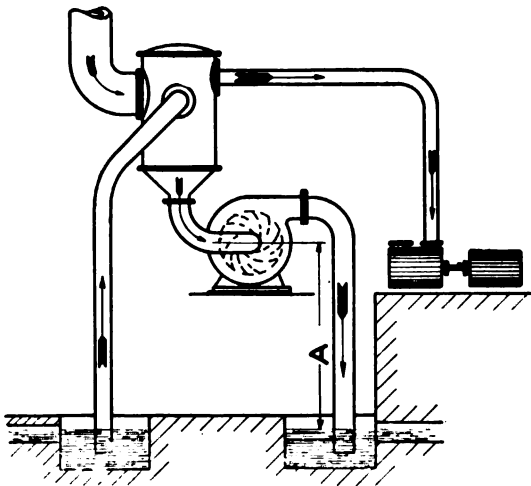
FIG. 17

Centrifugal Jet Condenser—This is closely allied to the last mentioned type, the only difference being that a centrifugal pump is employed instead of the reciprocating pump but, as the centrifugal pump as generally arranged is not capable of handling air, an additional dry air pump must be employed. A general arrangement of this is shown in Fig. 17. For condensers of large capacity, the centrifugal jet type lends itself readily to design and in such cases works out in less cumbersome apparatus than the plain jet. The

Leblanc condenser is essentially of this type, the difference being really only in the type of air pump.

The Leblanc condenser may be regarded as a great achievement, inasmuch as the cumbersome dry air pump is supplanted by a very small piece of rotary apparatus which may be mounted on the same shaft with the centrifugal discharge pump, thus requiring but one engine or motor to drive it, the combination making an exceedingly simple and desirable piece of apparatus.

Barometric Jet Condenser or Elevated Condenser—This is an excellent and efficient type of condenser for certain locations of source of cooling water, etc. The general arrangement is shown in Fig. 18. The condenser *A* is elevated higher than the height of the barometric water column above the level of the hot well, so that, unlike the two previous types of jet condensers, the cooling water has to be pumped into it, but does not have to be pumped out. It runs out by gravity. There are cases, however, where the source of the water supply is at a certain elevation and is discharged to a hot well at a lower level—some six or eight feet difference being enough to render no water pumps of any kind necessary.

FIG. 18

Such a location might be encountered in a power plant that is an auxiliary to a water power plant where the condensing water is taken from above the dam and discharged below.

The only difference between the barometric jet and the centrifugal jet is that the former requires means of getting the water into it, the mixture of condensed steam and water coming out by gravity, while with the latter the cooling water goes in by gravity; that is to say, it is sucked in by vacuum, but requires means for discharging it. So far as the air pump is concerned, the one that is suitable for one type is suitable for the other.

Ejector Condenser—This is a very interesting type of barome-

tric condenser in which, immediately below the condensing chamber, are formed cones which permit the descending water to entrain air with it so that no air pump is required at all, and in certain very favorable instances where the source of water supply is materially higher than the level to which it is discharged, not even a water pump is required. Notable examples of this type of condenser are the Bulkley, Baragwanath and the Schutte & Koerting. It may be stated as a general proposition that these types of condensers require more cooling water than others; in other words, the temperature difference, the smallness of which is a measure of condenser performance, must always be pretty high. Furthermore, they are more susceptible than other condensers to air leaks; that is, a given air leak will produce a greater fall of vacuum.
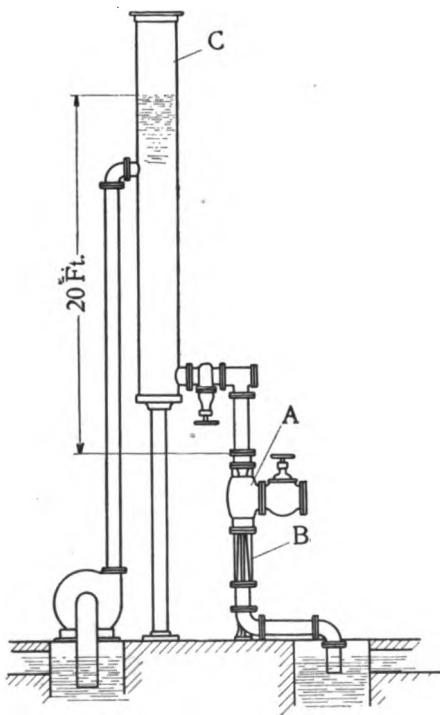
FIG. 19

While these condensers are also of the barometric type, Schutte & Koerting, however, build an ejector condenser which has no barometric tube, as shown in Fig. 19. The water is pumped into a condenser *A* under such a pressure that it issues out through a diffusing tube *B* with a high enough velocity to carry with it the air and condensed steam with sufficient energy to discharge it against atmospheric pressure. The open stand pipe *C* is open at the top, permitting a quantity of the air entrained with the injection water to escape, preventing it from impairing the vacuum.

There are limits to the capacity to which ejector condensers may be built, as twin condensers are generally seen for outfits of as large capacity as 1 500 kw. There was an installation of a Bulkley condenser at the plant of the Atlantic Mills, Providence, R. I., in

connection with a 400 kw turbine which it is understood has been giving good results. At all events, this jet condenser was the sub-ject of a paper read before the American Society of Mechanical Engineers by George I. Rockwood at the December meeting in 1906. The interesting parts which it is desired to bring out are some pecu-liarities that were encountered in installing this condenser. As Mr. Rockwood first installed it, the injection pipe was led upwards and then horizontally some distance before going into the condenser, when he could get but 20 inches vacuum. On Mr. Bulkley's advice, born of experience, the horizontal run of pipe was done away with and a 28-inch vacuum was at once obtained.
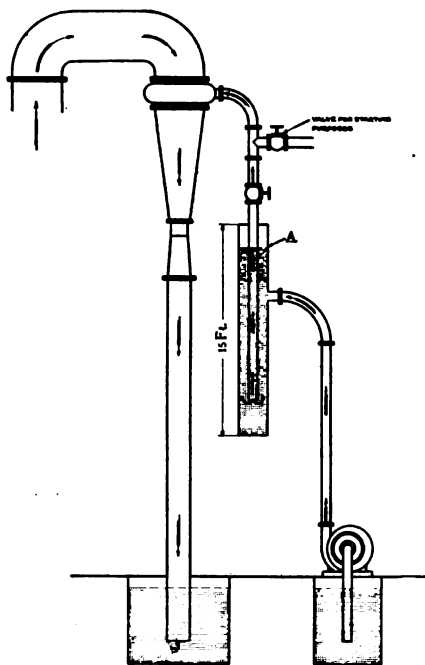
FIG. 20

Another difficulty encoun-tered in this installation was due to air being drawn in with the injection in spite of the suction being well submerged. As first installed, a plain pipe was led up to the top of the condenser. This, however, was altered and a vertical open tank was installed and ar-ranged as shown in Fig. 20. The tank *A* was 15 feet in depth which Mr. Bulkley said was the requisite depth in or-der to squeeze out all the air. It is understood from Mr. Rockwood that the installation of this tank was of great bene-fit and at any time one could look into the tank and see bub-bles of air rising to the surface in great quantities. It will be noted that this tank is exactly the same in effect as the open stand pipe in the Schutte & Koerting condenser, Fig. 19.

Rotary Blower Type—This type is equivalent to the centrifu-gal jet, except for the method of handling the air, and that a rotary pump of the Connersville Blower type is used instead of a centrifugal pump. A connection is taken from the condensing chamber in the same manner as in the usual barometric or centrifu-gal jet condenser and leads direct to the rotary pump which en-

trains the air, thus avoiding the necessity of a separate air pump. The rotary pump being water sealed, can operate with some clearance. So far it is undersood that these have given good results, but obviously any corrosion of pump runners or cylinder walls will interfere with the efficiency. The effect of "nails," "jack knives," etc., carried in with the cooling water would be disastrous.

Counter-Current Principles—Some condenser builders lay great stress on the fact that they design jet condensers on the counter-current principle. The Weiss condenser, developed in Germany and manufactured in this country by The Southwalk Foundry & Machine Co., is, probably, the first type where the builders laid stress on this principle. How necessary this counter-current principle is would seem to depend upon whether the greatest amount of air enters the condenser by means of the cooling water or with the exhaust steam. If, in contemplating the counter-current principle, one supposes that all the air enters the condenser with the cooling water, he wonders how any kind of a high performance could be easily and economically obtained with any condenser that did not have due consideration given to this matter.
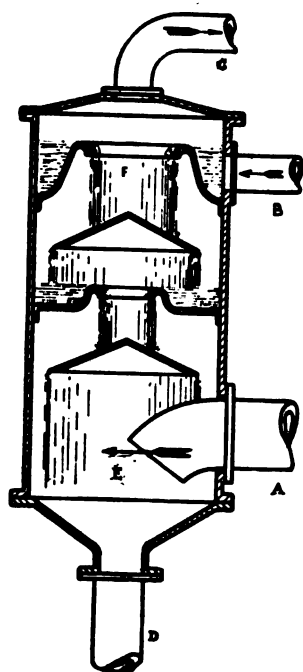
The principle may be further exhibited in Fig. 21 as it would be applied to either a barometric or a centrifugal jet condenser. The exhaust steam enters at *A*, the cooling water at *B* and the air is withdrawn at *C*. The mixture of condensed steam and water issues at *D*. The air, then, is drawn out from the portion of the condenser at which the cooling water enters where the temperature is lowest and where air tension predominates materially over vapor tension. At the other part of the condenser where steam enters, the opposite condition exists, viz., the vapor tension predominates over the air tension. It is well known that, if a vessel containing water of a certain temperature is connected to a vacuum pump, no matter how high a vacuum this pump is capable of maintaining, the vacuum in the chamber can never be higher (that is,

FIG. 21

have less pressure) than the pressure corresponding to the temperature of evaporation of the water. And if the air is at a lower temperature than the water, the pump does not have to pull a theoretical vacuum in order to bring about evaporation. This explanation may be made clearer by taking a concrete case.

Let us say this condenser is operating at a 28-inch vacuum and that the condenser performance is ideal, so the temperature of the mixture leaving the condenser will be the same as the temperature of the exhaust steam which is the temperature of evaporation at 28 inches vacuum, viz., 101.9 degrees. Therefore at the zone E in Fig. 21, the pressure will be one pound absolute and the temperature 101.9 degrees. Then suppose that the temperature of the cooling water entering the condenser at B is 70 degrees; so that the temperature at zone F in condenser is 70 degrees. For all practical purposes it may be assumed that the pressure at zone F is the same as at zone E, viz., one pound absolute.

Now the vapor tension corresponding to 70 degrees is 0.36 pounds absolute, (at 0.36 pounds the temperature of evaporation is 70 degrees). The actual pressure at the zone F is, however, one pound per square inch absolute. Hence 36 percent by volume of the mixture at F is vapor tension and 64 percent is air tension. Here it must be remembered that the condenser is operating ideally and hence it might be supposed would require an air pump to pull a perfect vacuum, but, by reason of the relative tensions and the air pump drawing its air from where the air tension predominates over vapor tension, this is by no means the case. In the concrete example an air pump which with the certain given air leakage in the condenser system, will pull a vacuum of 0.64 of a pound absolute pressure or within 1.3 inches of the barometer is all that is required. This figure, 0.64 pounds, is the difference between the pressure at the temperature of evaporation at 70 degrees, viz., 0.36, and the pressure in the condenser, viz, one pound absolute. Of course, as the air pump reaches this condition, the zone of condensation in the condenser moves from E towards F and this will continue until some steam will be drawn away through the pipe to the air pump. To provide against any trouble from this, the Weiss condenser is arranged as in Fig. 22 with a supplementary small tail pipe A, as shown, discharging into a supplementary hot well with the draining spout B a trifle higher than the drain C from the main hot well. In the path of the water draining the supplementary hot well, is arranged a bucket in combination with a lever

and small valve *D*. The bucket has a small hole in its bottom so as to permit ordinarily small quantities of water to drain through, but as soon as the water flows in a material quantity the bucket is overbalanced and, by means of the levers, opens a small valve, admitting air to the condenser. This has the immediate effect of raising the temperature of evaporation, when the zone of condensation in the condenser cone will be lowered.
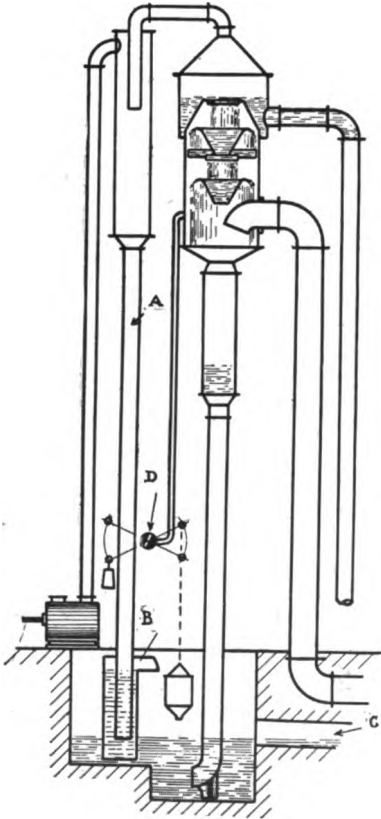
FIG. 22

The cycle of events is therefore as follows: The moment the air pump *E* begins to pull a vacuum equivalent to the temperature of evaporation or, in the concrete case referred to, 0.64 pounds absolute, the pumps will begin to draw steam with some water. This discharging down the auxiliary tail pipe and filling the bucket, opens the air valve, immediately dropping the vacuum, when steam and water will cease to come over and the bucket will rise to the normal position.

Referring again to Fig. 21, the temperature at zone *E* will correspond to the temperature of evaporation at the exhaust temperature. This temperature becomes less and less towards zone *F* where the temperature is least and corresponds to the temperature of the injection.

As has been stated, it is only some condenser builders that make use of this counter-current principle just described. All of them, however, make some attempt to cool the air on its way to the air pump. In view of the results obtained under proper conditions with condensers not involving the counter-current principle, it would almost seem that this cooling of the air answers the purpose, but unless some reasons, mechanical or otherwise, exist which make it difficult to accomplish, it is believed the counter-current

principle is the right one to adopt. In the case of the Leblanc con-
denser the counter-current principle in any special cooling device
is unnecessary, as the water used in the actuation of the air pump
entirely performs these functions.

In all condensers where the exhaust steam has to be elevated
to some height and where the horizontal run of the exhaust piping
is of any material length before the steam is carried upwards to
the condenser, it is very desirable to install what is known as an
entrainer. In Fig. 18 at *B* is shown one of these in connection with
a barometric condenser. By this means any water that may be
present will drain to the lowest portion of the entrainer. As soon
as this fills up sufficiently to obstruct the flow of steam, the volume
of water, being so small, is readily picked up by the steam and car-
ried upwards to the condenser. Without an entrainer a long ex-
haust pipe would hold a great quantity of water which, as soon as
enough has accumulated to cause slight obstruction to the steam,
will surge back and forth in waves, causing serious water hammer.
Large heavy exhaust pipes have been known to be completely
wrecked from this reason. It has also happened when operating
turbines at light load and when the accumulation of water is the
greatest, that this surging of water in the pipes has taken place
with sufficient force to surge back into the turbine, thus rip-
ping out the low pressure blades. Whether there is an entrainer
or not, there will always be some pressure drop in the exhaust
pipe when condensers are elevated. This is generally termed "en-
trainer loss."

At time of light load there will be the greatest accumulation of
water and, on the load being increased, the pressure drop will be
temporarily greater. Similarly, when the load is reduced, the pres-
sure drop will disappear, afterwards returning to normal as soon
as the water has accumulated. The normal pressure drop, or en-
trainer loss, amounts to from one-fourth to three-eighths of an
inch on a mercury column.

Where the horizontal run of exhaust piping before the riser
to the condenser is very short, no entrainer is necessary, as obvi-
ously the steam coming out of the bottom of the turbine, then turn-
ing horizontally through a very few feet of pipe and then rising, is
itself as entrainer. Just what length of pipe necessitates an en-

trainer can only be arbitrarily determined.   The writer recommends that, where the horizontal pipes are more than six diameters long, an entrainer should be installed.

This entrainer loss may be entirely eliminated by placing a chamber at the base of the up-take to the condenser into which any water will drain and, in conjunction with this, employing a small pump, preferably controlled by a float valve, which will keep the water below a certain level.   Similarly, a small centrifugal pump driven by a high-speed motor kept continuously in operation would fulfill this office very nicely.   Either method is preferable to an entrainer except that there would be additional pieces of running machinery to be taken care of.   However, assuming the entrainer loss to be three-eighths of an inch of mercury, this means a loss of a trifle more than one percent in the capacity of the turbine. So that in a condenser in conjunction with a 10 000 horse-power outfit, a pump of approximately half a horse-power would enable the turbine to produce 100 horse-power more for the same fuel consumption and would be worth a little care and attention.

Sometimes the entrainer may be drained directly to the air pump suction when a wet air pump is employed and when the relative elevations of exhaust pipe and air pumps permit a free fall to the pump.   Generally, where possible, exhaust pipes should be led down to the condenser, permitting free draining.   A point worth keeping in mind when it is desirable to arrange condensers in groups is to prevent a condition of unstable equilibrium where the cooling water will all tend to run to one condenser.   This condition will take place where one engine or group of engines are arranged to exhaust into a group of condensers.   The moment a little more water tends to go to one condenser than another the vacuum will rise in that condenser and more water will flow to it and in the meantime the vacuum will drop in the other condensers.   The operator, seeing his vacuum on the system has fallen to that corresponding to the condenser starved of water, will attempt an adjustment of his injection valves which will last for a time when a slight disturbance will perhaps send all the water to another condenser.   This difficulty is minimized if considerable pressure drop be allowed over the injection valve, but this may mean a loss of power.

<div align="center">(To be continued.)</div>

DETERMINATION OF RESISTANCES BY GRAPHICS

F. W. HARRIS

T HE use of graphical constructions for the solution of static problems and their use in alternating-current analysis are matters of common engineering practice. The development of particular graphics for special purposes, however, is not so common, due probably to a lack of appreciation on the part of the majority of engineers of the conveniences offered by their application. The following development of a method, by which the complex calculations required in designing resistances for motor control equipments to give certain conditions of acceleration are made with ease and clearness by graphic solution, is not only instructive in its bearing on this particular subject, but suggestive of convenient applications of the simple graphical constructions to various other problems which ordinarily require elaborate calculation.

RESISTANCES IN SERIES

There have been numerous discussions in regard to the proper number and proportions of steps to use in various motor starting

FIG. I
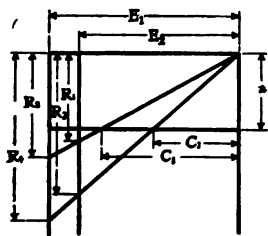
resistances. This is not a very difficult matter to determine on the assumption that the fluctuation in current at each change in resistance is limited to a constant value, i. e., the start is made with a given current which is cut down by the counter-e.m.f. of the motor to a certain value, when it is again increased to its initial value by cutting out the resistance. A graphical expression of Ohm's Law is given in Fig. 1. This is based on the use of similar right triangles. Thus, R_1, the short side of one triangle, is to a, the corresponding side of a similar right triangle, as the medium side E_2 is to the medium side C_1, or $R_2 : a = E_2 : C_1$. This is obviously Ohm's Law or $E_2 = C_1 R_1 \div a$, the value of a being merely a convenient scale factor. For example, if a be made equal to *one* it disappears. The introduction of the factor a serves to give a convenient shape to the reference triangle. In a similar manner, $E_1 = C_1 R_3 \div a$.

Considering now the starting of motors, the simplest case is that in which the motor has absolutely constant field strength. These

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conditions are shown in Fig. 2. It is assumed that the motor starts with a current value of C_1, and a voltage E_1 impressed on the circuit (shown graphically by $E_1 E$). It is evident that a resistance $R_1 R$ is required. The motor, in accelerating develops a counter-e.m.f. represented by $E_1 E_2$, and when the current reaches a value C_2, a resistance must be cut out to bring the current value back to C_1. Following the line $S_1 E_2$ vertically towards E_2 to the point where it intersects the diagonal, $R_1 E$, it is seen that the line $R_2 R$ represents the remaining resistance, the value $R_1 R_2$ being the amount cut out. It follows, therefore, that a repetition of this process gives successive resistance points, $R_1 R_2 R_3$, etc. Each step cut out is a certain percentage of the total resistance in circuit at that instant. It is evident then that, theoretically, the number of steps is infinite. It should be borne in mind, however, that the resistance $R R_1$ is the total resistance in circuit and includes the resistance of the motor and wiring which cannot be eliminated. It may be assumed, for example, that this resistance is equal to $R_7 R$, in which case the number

FIG. 2

of steps would be six. Assuming the motor to have a constant acceleration, it is evident that the counter-e.m.f. will increase uniformly, which means that time may be measured from left to right along the line $E_1 E$, equal intervals denoting equal time intervals. In this case the rheostat handle evidently should remain a long time on the first step and a shorter time on each succeeding step, the time intervals following the same law as the resistance. It is also evident that the magnitude of the resistance steps is independent of the time interval if the resistance changes are made at the proper current values, the time interval depending on the rate of acceleration.

In such a motor, having a constant flux with a maximum current C_1 and a minimum current C_2, there should be cut out on each step a portion of the whole resistance represented by the ratio $(C_1 - C_2) \div C_1$. The resistance values depend wholly on the cur-

rent and the time intervals wholly on the speed of acceleration of the motor.

The foregoing assumes that a certain maximum and a certain minimum current are controlling factors. Fig. 3 shows a construction in which a certain maximum current C_1, measured by the line $C_1 C$, and equal increments of counter-e.m.f. between steps are assumed, the minimum current and resistance being the dependent variables. The first resistance value is $R_1 R$; the second, $R_2 R$, etc. $E_5 E$ is assumed to be the drop due to the resistance $R R_5$ of the machine at current $C_1 C$. The line $E_1 E_5$ is then divided into four
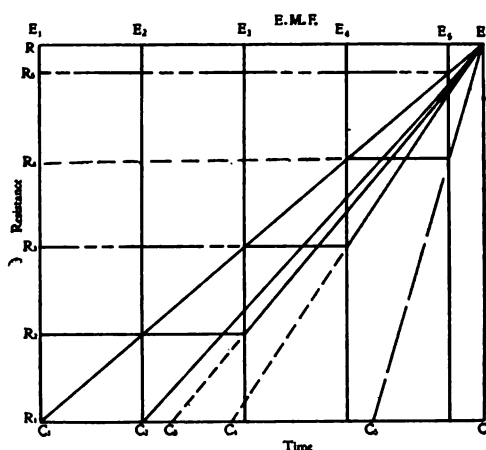
FIG. 3

parts. If this motor were connected to a load having considerable fly-wheel effect, so that the fluctuation in acceleration due to changes in current caused by cutting out the resistance step-by-step are prevented, the line $E_1 E$ would also be a measure of time since the counter-e.m.f. would increase uniformly. Or, if the number of steps were made very great, the current fluctuation would become very small, and the motor would be uniformly accelerated. In that case, cutting out equal resistances in equal time would result in a certain maximum current at the beginning of each step and a constantly diminishing current at the end of each step.

In proportioning the steps in a starting rheostat for shunt or compound motors a design following the method of Fig. 1 would lead to the best theoretical results as regards smooth starting, but would necessitate shortening the time intervals as the rheostat arm was advanced. The second condition as outlined in Fig. 3 would

not give as uniform an acceleration due to wide current variations and consequent torque variation, but would prevent the blowing of fuses and allow uniform movement of the arm. It is evident that a skillful operator could start a motor with either, and in all probability the best starter would be a compromise.

The above applies only to motors having constant fields. Railway motors having series fields require a somewhat more complicated diagram due to the fact that in cutting out a step of the resistance the current jumps from a low to a higher value with consequent change in field and counter-e.m.f. If the iron of the field is worked very low this increase in counter-e.m.f. is directly pro-
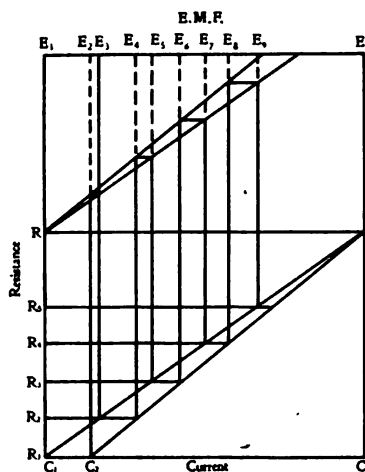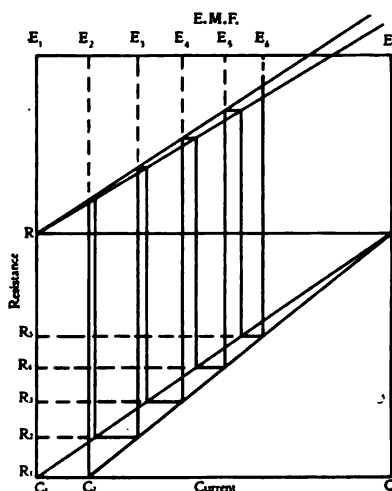
FIG. 4   FIG. 5

portional to increments of current. Fig. 4 shows a construction in which this is true. In this figure there is an upper rectangle carrying another pair of diagonal lines. This is to take care of increments of counter-e.m.f., the horizontal distance between the lines being proportional to their increments, or $C_1 C_2 : C_2 C :: E_2 E_3 : E_2 E_1$. The resistances are measured downward from R as before. The maximum current is $C_1 C$, and the minimum current is $C_2 C$.

With the maximum current flowing, $R_1 R$ is a measure of the total resistance in circuit. If the motor is now accelerated, a counter-e.m.f. will be developed, and when it equals $E_1 E_2$ the minimum current $C_2 C$ will be reached. It is now desired to cut out enough resistance to bring the current up to $C_1 C$. In increasing this current the counter-e.m.f. $E_1 E_2$ will increase to $E_1 E_3$ as indicated by

the horizontal line connecting the upper diagonals. Dropping the perpendicular E_3 to intersect the diagonal to C_1, line $R R_2$ will indicate the resistance. If the increase in counter-e.m.f. is directly proportional to increase in current, the resistance steps will be equal, and if the current limits are small enough to prevent speed fluctuation, time may be measured on the top line as before, $E_1 E_2, E_3 E_5$, etc., being equal intervals. It is seen then that a series motor with a field in which the iron shows no saturation can be started with definite current limits by equal steps cut out in equal times.

In all commercial series motors some saturation is present. The greater this saturation, the nearer the conditions approximate those of Fig. 2. The construction for an actual case is given in Fig. 5, in which the saturation makes the increase in counter-e.m.f. only one-half that which would result if it were proportional to the change in current. This results in a gradual cutting down of size of steps and a similar cutting down of time intervals. That is to say, a railway controller must be moved faster on the last notches than on the first and the last resistance steps must be less in proportion.

The results of the four cases above may now be considered as regards time and resistance only. Assuming that the curve representing the motor acceleration is a straight line, the spaces along the upper line $E_1 E$ represent equal time intervals. An inspection of Fig. 2 shows that the changes in e.m.f. or speed follow the same law as changes in resistance, i. e., that while the values of successive resistance steps diminish, the length of time they are in circuit diminishes in the same ratio. The rate of cutting out resistance is therefore constant. A careful analysis of other figures shows this to hold good throughout. To accelerate a motor uniformly with a constant or variable field, the resistance should be cut out at a uniform rate. The values of successive steps and the character of the motion of the moving arm follow the same law and are determined by the characteristics of the motor. The practical deduction, then, is that if an arrangement could be obtained whereby the resistance could be decreased uniformly, i. e., without steps, as in a water rheostat (where adjustment of the plates determines the resistance), the desired condition of uniform acceleration would be realized, regardless of the character of the motor field, because with uniform acceleration the current is constant, the field is constant, and therefore its characteristics have no bearing on the case.

The above graphic representations show clearly to the eye the relationship of the electro-motive force, current, resistance and time. In the solution of actual problems, it is found that a larger current is needed on the first step than on the succeeding steps and that the acceleration is rarely along a straight line. In nearly all cases the character of the acceleration is not important and most designers have a favorite choice of curve along which they place resistance values. For railway motors this curve may be about that shown in Fig. 6, the straight line being given for reference. The theory is as presented above and in the case of very large units, such as motors, driving rolls, etc., where the character of the acceleration and the saturation curve are known, the actual resistance requirements may be worked out by these methods.

<div align="center">RESISTANCES IN PARALLEL</div>

In the case of resistances of heavy capacity, it is found difficult to obtain low enough values without putting several resistance units
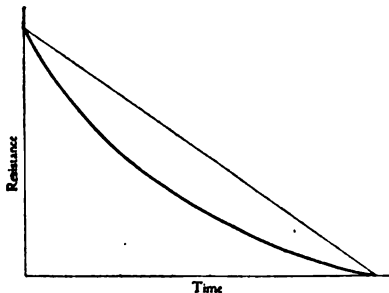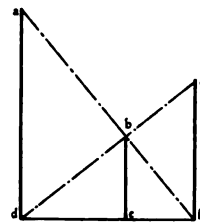
<div align="center">FIG. 6   FIG. 7</div>

in parallel. In such cases in the place of putting all the resistance in circuit and then cutting it out step by step, it is found advisable to put a single section in circuit and then throw additional sections in multiple with this. By doing this each succeeding contact of the controller handles larger current. The last step is of course made by closing contacts which short-circuit the combination.

The calculation of parallel resistances is a somewhat tedious task, while the construction shown in the following figures is quick and accurate. It is founded on the well known construction for solving parallel resistances shown in Fig. 7. In this figure, *ad* and *cf* are the given resistances placed at any convenient distance apart on the base line *df*. The construction lines *af* and *cd* are then

drawn and the line *be* from their intersection to the base line is the resistance of *ad* and *cf* in parallel.

The application of this method to an actual resistance problem is shown in Fig. 8. Assuming that it is desired to select resistances to give, in five steps, an acceleration which will follow a curve similar to that shown in Fig. 6. The first resistance value is *ad,* the second, *be,* the third, *hi,* the fourth, *lm,* the fifth step being located at *p* and being zero. The proportion of the individual resistances which will give these values are determined as follows: It is evident that the first resistance will be *ad.* It is now required to find another resistance which, in multiple with *ad,* will give *be,* the second resistance value. Drawing *abf* through *a* and *b,* and erecting a perpendicular at *f,* a new value, *cf* is given by the intersection of this perpendicular with the line *dbc.* In a similar manner *bhk* is drawn, a perpendicular is erected, and the line *ehj* is
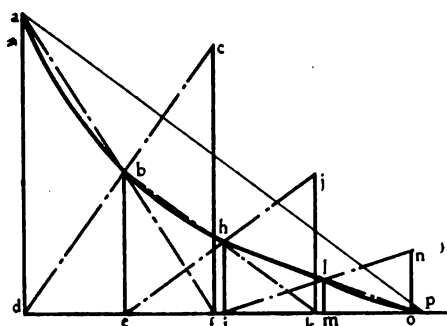
FIG. 8

drawn, thus determining *jk* as the third step. The fourth resistance is, in a similar manner, found to be *no.*

It is thus determined that, to produce a resistance curve passing through *a, b, h, l,* and *p,* the resistances *ad, cf, jk* and *no* must successively be thrown in multiple, all finally being short-circuited at *p.* By a similar application of the method the same curve may be approximated, using a different number of steps. With corresponding calculations, made for various other acceleration curves and showing on the same sheet the resistance and time or "steps" co-ordinates, both being expressed in percentages, a graphic calculation sheet may be prepared to cover a complete set of conditions such as would be required for a given line of apparatus, the results for a specific case then being expressed in percent of the total resistance. The resultant is thus immediately obtainable.

The graphic method was recently used in the solution of a problem on parallel resistances, for which it proved to be a very simple method, whereas, the derivation of a mathematical formula which would give a reasonably simple and rapid solution proved to

be rather involved.*   A system of trolley feeders was connected as shown in Fig. 9, the resistance of each section being known, and it was desired to find the equivalent resistance of this combination. The graphical solution is shown in Fig. 10.   The construction is as follows: Lay off a base line, AB, of any convenient length, and represent the respective resistances by line perpendicular to this base line and draw to scale as follows: At A, let AC represent r_1 and CD, r_5 on the same straight line.   At B, let BE represent r_2; then GF, determined by the intersection of diagonals DB and EA, represents the resultant of $r_1 + r_5$ in parallel with r_2.   Lay off EH equal to r_5 in the same straight line as BE. Then likewise, JK repre-
sents the equivalent resistance of
$r_2 + r_5$ in parallel with r_1.   At
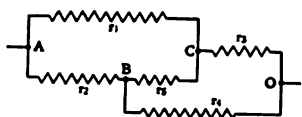
FIG. 9
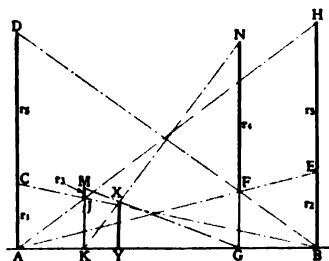
FIG. 10

the point J lay off JM, representing r_3, in the same straight line as JK; likewise, at F lay off FN, representing r_4.   Draw the diagonals NK and MG; then the line XY is determined by their intersection and represents the equivalent resistance of the five resistances as connected.

*See No. 316 in THE JOURNAL Question Box.

VOLTAGE REGULATING RELAYS

PAUL MacGAHAN

VOLTAGE regulating relays are used principally in connection with motor-operated feeder regulators to start, stop and reverse the motor as the voltage changes, and thus cause the regulator to maintain the voltage of the circuit under its control at the predetermined normal value. In general the relay outfit for each regulator comprises a primary relay or a "contact-making voltmeter," and a secondary relay or motor starting switch electrically operated by the contacts of the primary relay. It is necessary to use separate relays, as a primary relay having the necessary accuracy and freedom from errors due to temperature and frequency variation cannot be made powerful enough to control the heavy contacts necessary to open and close the motor circuit.

Previous Difficulties—One of the difficulties encountered heretofore has been that there was a tendency for the movable contact to remain very near one of the stationary contacts, thus causing unnecessarily frequent operation. This was caused by the relay opening the contact when the voltage was equal to that at which the contact closed. Therefore the tendency of such a relay was to keep the voltage, for example, at $99\frac{1}{4}$ or $100\frac{3}{4}$ volts, if the stationary contacts were set for a normal voltage of 100, plus or minus $\frac{3}{4}$. The principal drawback, however, was that the contacts of the primary relay would often vibrate or chatter when the voltage approximated that required to close them, thus causing the contacts to barely touch and make a succession of poor contacts. This produced arcing, burning or freezing of the contacts and pitting, despite the fact that the contacts were made of the rarer metals of the platinum group, so alloyed as to have extreme hardness and high melting point. The poor contacts in the primary relay in turn caused chattering of the secondary relay with the resultant wearing out and burning of its contacts, thus increasing the noise, the heat-

FIG. I—INTERIOR VIEW OF PRIMARY VOLTAGE REGULATING RELAY

ing of the motor, and the general wear and tear on the whole outfit.

Present Arrangement—It was to overcome these objections that the following novel arrangement was developed: To the primary relay or contact-making voltmeter were added two auxiliary windings, each in series with one of the two contacts and so arranged as to assist in closing the contacts, by increasing the torque just as the contact is closed. The current passing through these coils and contacts actuates the secondary relay or motor switch which controls operation of the motor on the regulator.

A general view of the primary relay is given in Fig. 1, clearly showing the stationary and moveable contacts, made of specially alloyed metals of the platinum group, and so mounted as to give a wiping or self-cleaning action when making contact. An auxiliary relay is shown in Fig. 2. Fig. 3 is a diagram of connections between the circuit being regulated and the primary and auxiliary relays, showing the auxiliary coils of the primary relay and the motor control circuits.

The proper compounding action from a primary relay auxiliary coil is found to be obtained when it is arranged to

FIG. 2—INTERIOR VIEW OF AUXILIARY RELAY
With oil tank removed.

have ¾ percent of the torque of the main coil. There is a non-inductive resistance in parallel with each coil of the secondary relay, which takes currents approximately in phase with the current in the main coil of the primary relay and of proper strength to make the ampere-turns in the auxiliary coils of the primary relay ¾ percent of that in the main coils. In addition, these coils absorb the "discharge" from the main coil of the secondary relay when the contacts are broken, thus greatly reducing sparking at the contacts.

Assuming that the contacts are set for a regulation of plus or minus ¾ percent; when the voltage to be regulated rises ¾ percent, the primary relay contact closes, and the extra effort of one or the other of the auxiliary coils *a*, Fig. 3, makes this closing positive, thus avoiding chattering and burning. An additional advantage is

that the contact remains closed until the voltage is reduced by ¾ percent, or, in other words, returned to the normal point exactly, when the contact is again broken suddenly and positively, thus avoiding sparking. No further contact is made until the voltage again changes ¾ percent; thus the life of the primary and secondary contacts is greatly increased, also the motor will run cooler and there will be less wear upon the mechanism.
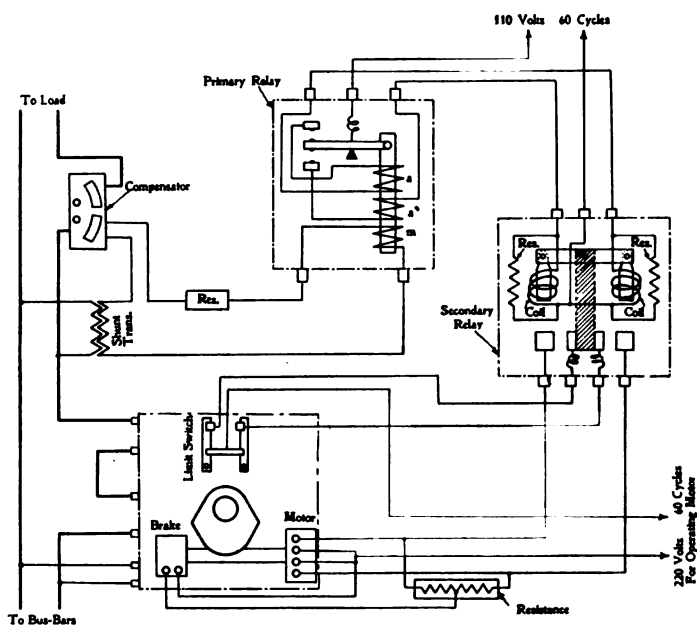
FIG. 3—CONNECTION DIAGRAM OF MAIN AND AUXILIARY CIRCUITS OF MOTOR-OPERATED INDUCTION REGULATOR CONTROLLED BY MEANS OF PRIMARY AND SECONDARY VOLTAGE REGULATING RELAYS

In order to obviate the objectionable flashing at the contacts of the auxiliary relay, to reduce the noise and to greatly increase the life of the contacts, the auxiliary relay is made of the oil immersed form, the contacts being under oil.

THE JOURNAL QUESTION BOX

313—Low-Voltage Release Used in Connection With Automatic Oil Switch—Please explain, with the aid of a diagram, the connections necessary for a low-voltage release coil such as would be used in connection with an automatic oil switch intended for a 440-volt, 400 hp, three-phase induction motor. The current transformers supplied with the switch have a ratio of 600 to 5 amperes. The two overload trip coils are connected to the secondaries of the three current transformers as shown in Fig. 313 (a). The oil switch is to be located at the point where the motor circuit is connected to the main, and it is desired to operate the low-voltage release from a point near the motor. Please give the direction and value of current in the relay coils and state whether inserting the low-voltage release coil will affect the present adjustment of the overload trip coils.   O. B.

The no-voltage coil may be connected across any phase of the line and at any convenient point, as its action is entirely separate from, and independent of, the overload coils and the series transformers to which they are connected. While there is a remote possibility of failure of voltage on one phase of the circuit alone, i. e., without failure on all three phases, the probability of such an occurrence is so slight that it may be safely assumed that a single no-voltage coil will satisfactorily take care of abnormal conditions arising through failure of voltage, especially where a motor circuit is involved. The low-voltage release coil is shown in Fig. 313 (a) connected directly to

one phase of the motor circuit. These coils are adapted for direct connection to circuits the voltage of which does not exceed 440 volts. For use in conection with circuits of higher voltage than this, it is necessary to insert a voltage transformer between the release coils and the line circuit;
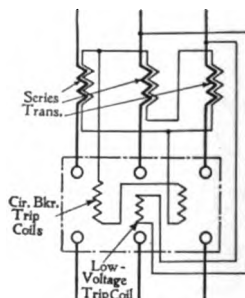
FIG. 313 (a)

the action of the release coil being the same with or without the transformer.   H. G. MacD.

314—Excessive Drop in Alternating-Current Feeder Circuits —Two 60-cycle multiple arc circuits, the general dimensions of which are indicated in Fig. 314 (a) are carried on a pole line having two cross arms per pole. The arrangement of the two arc circuits is shown in Fig. 314 (b), *a* and *b* being the feeders for one circuit and a' and b' those for the other. Several heavy direct-current feeders are also carried on the same cross arms. A test developed the fact that, with a current of about 100 amperes, and a line voltage at the step-down transformers in the sub-station, of 118 volts, the volt-

age available at the first arc lamp was only 85 volts, representing a drop of 33 volts in 1 200 feet of circuit. At a point 300 feet from the station the drop was found to be 10 volts. The theoretical, *i. e.,* calculated value of the drop to the center of distribution is less than 15 volts. Would the arrangement of the wires on the poles affect the drop? According to my figures this is negligible. All the wire is new and apparently in perfect condition. The twelve lamps are new multiple 7.5 amperes. Will you please suggest an explanation of the excessive drop?   J. W. G.

The inductive resistance of a single-phase circuit, 1 000 feet long, is given by the following formula: $2 \times 2 \pi f \times$

$(0.0152 + 0.14 \ \log. \frac{d}{r}) \div 1\,000$, in

which f = frequency, d = distance between centers of wires, and r = radius of wire. This expression

12000/120 V.Trans. ⁰0000 B.& S.   12 Multiple Arc Lamps
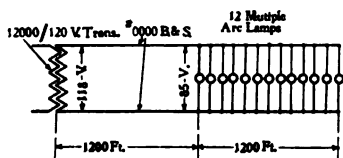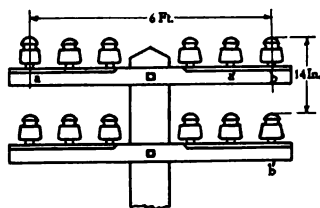
FIG. 314 (a)

FIG. 314 (b)

gives the drop for one ampere transmitted 1 000 feet. By this formula a circuit of 1 200 feet of 0000 copper wire, with 72 inches between centers, and carrying current at 60 cycles, is found to have an inductive drop alone of about 33 volts, which, combined with the ohmic drop of 12 volts, with a current of 100 amperes, gives a total drop of about 35 volts. If the

two circuits run parallel for some distance, it is possible that the inductive drop can be neutralized by placing the two circuits as close together as is safe, connecting so that the instantaneous directions of flow of current are opposite in adjacent wires. If the two circuits are separate for a considerable part of the total distance, the inductive drop in each circuit can be reduced by keeping the two wires of each circuit as close together as is safe for operating conditions.

R. P. J.

315—TESTING OF INSULATORS—Will the results of breakdown tests on insulators, etc., be materially affected due to generator e.m.f. wave form by using a polyphase generator to supply single-phase power? The voltage is to be measured on the low-tension side by using an ordinary indicating voltmeter, which measures the effective value of the wave, while the breakdown voltage depends upon the maximum of the wave. What size generator is it advisable to install for such tests? What percent of generator rating can be obtained when using a polyphase generator as single-phase?   C. W. S.

As the power required for such tests is determined simply by the electrostatic capacity of an insulator, only a small power generator is necessary, unless the test is conducted simultaneously on a large number of insulators. The wave form of alternators of comparatively recent design approximates very closely to that of the sine wave and is not affected by the number of phases involved. The single-phase capacity of a three-phase generator is 71 percent of the three-phase capacity. The voltage for a test such as that under consideration should be measured by means of a spark gap, the terminals of which should be mounted on insulators of the proper size and which should be equipped at the gap with "bull-nose" or spherical points of one-half inch diameter. Curves or tables giving the equivalent voltage for a given length of gap are to be found in the various handbooks for electrical engineers. For further

suggestions in connection with this subject note article on "Design and Testing of Electrical Porcelain" by Dean Harvey in the JOURNAL for October, 1907, p. 568. C. E. S.

316—RESISTANCE OF INTER-CONNECTED FEEDERS—A system of trolley feeders is connected as shown in Fig. 316 (a), the resistance of each section being known. What is the equivalent resistance from A to O expressed in terms of the resistance of the respective sections? F. F. S.

Designating the resistances as r_1, r_2, r_3, r_4, and r_5, respectively, the combined resistance R from A to O
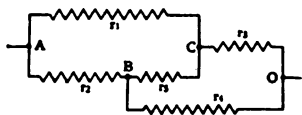
FIG. 316 (a)

may be obtained by means of the following formula:

$$R= \frac{r_1\,r_2}{r_1+r_2+r_5} +$$

$$\left[\frac{\left(\frac{r_1\,r_5}{r_1+r_2+r_5}+r_3\right)\times\left(\frac{r_2\,r_5}{r_1+r_2+r_5}+r_4\right)}{\left(\frac{r_1\,r_5}{r_1+r_2+r_5}+r_3\right)+\left(\frac{r_2\,r_5}{r_1+r_2+r_5}+r_4\right)}\right]$$

This expression will be reduced to comparatively simple form by the substitution of known values in the expressions $\left(\frac{r_1\,r_5}{r_1+r_2+r_5}+r_3\right)$ and $\left(\frac{r_2\,r_5}{r_1+r_2+r_5}+r_4\right)$ each of which is seen to recur twice in the formula, and therefore need be calculated but once. L. W. C.

317—BLUE-PRINT PAPER — The behavior of the enclosed sheets of blue-print paper has rather puzzled me. When the roll from which the samples sent you is opened in subdued daylight, the paper is found to be dark blue. If this paper be exposed under a tracing in strong sunlight for about two or three minutes, a very excellent print, consisting of blue lines on a white background is secured. If this print be now placed in water and left there about fifteen minutes, the whole sheet turns blue again. How can the print be "fixed" after exposure to sunlight, if such is possible? The paper is by no means new, having been purchased several years ago and kept in the dark ever since. A. L. M.

All blue-print paper when exposed under a tracing to strong light will show blue lines and a light background. If the blue-print solution on the paper is fresh, by washing in water, it will be found that the solution on the lines will dissolve and be removed by the water while the comparatively light background will be turned blue. If the solution on the paper is old, all parts have probably been affected by the light and heat during the storage period, hence, when washed, the water will not dissolve the solution on the lines but will change it to the same color as the background. We know of no solution or process of fixing the blue lines on the white background for old paper. A. B. R.

RELATIVE EFFICIENCY AND CAPACITY OF V-CONNECTED AND DELTA-CONNECTED TRANSFORMERS—What is the relative efficiency and capacity of transformers connected two on open delta on three-phase circuit as compared with three transformers connected in closed delta? P. H. P.

This is completely discussed in No. 21, Feb., '08, and 160, Oct., '08. Note also in this connection, No. 36, Feb., '08; No. 38, Mar., '08; Part (c) in No. 53, April, '08; and 162, Nov., '08. On p. 15 of the Five-Year Topical Index of the JOURNAL will be found a reference to the questions bearing on this subject.

NOTE.

In the sub-heading of the article by Mr. Cecil Lightfoot in the September issue, an error occurred in the use of the word "Chemical." This should have been "Mechanical," as the process is essentially a means of mechanical rather than chemical separation of the oxygen and nitrogen composing the air.

THE

ELECTRIC JOURNAL

Commercial Engineering

To specialization in the application of electricity is due the important increase in its use during the past few years. Electric power, electric lighting and electric heating have been put upon a new basis by the specific and effective adaptation of apparatus and methods to practical conditions. As a result, there is scarcely an industry that, for one reason or another, does not find the use of electric power advantageous not only in the ordinary and standard operations, but in the working out of new methods. In a recent engineering discussion in Pittsburg, Mr. Julian Kennedy, the noted steel engineer, said that he had been particularly impressed by the use of electricity in emergency conditions.

THE JOURNAL is planning several series of articles dealing with the application and use of apparatus in the electrical field, indicating the reasons why electric power is advantageous, and the most effective means for its application. More prominence will be given to what may be called commercial engineering as distinguished from design engineering. Such articles will pertain to the use rather than the construction and operation of the apparatus itself. This broadened scope will naturally interest a wider field of readers, as many men connected with various industries as engineers, operators, superintedents, managers and directors, who have more or less to do with electrical matters, will find in it the elements bearing directly or indirectly upon the problems which they have before them.

Several articles in this issue of THE JOURNAL deal broadly with the various applications of electricity. Mr. Scott considers the general question of the fundamental reasons or principles upon which the rapid advances in electricity have been made and upon which future development will probably be based. He seeks to generalize from particular results and advantages in specific cases to the broad underlying scientific and engineering reasons, which are the controlling elements.

The article by Mr. Popcke shows how a wattmeter can indicate the efficiency of shop organization and tool operation as well as kilowatts.

Mr. Sweet's article on "Standard Relations of Light Distribution" gives a clear insight into the relations between the inventor, the designer, the expert and the man by whom the ordinary practical work must be done. He shows the importance of following scientific principles in illumination and indicates the practical methods by which this scientific knowledge may be practically applied. In the next issue it is planned to publish a further discussion on this subject in which will be given the practical application of the principles laid down in the present article as a means of determining the proper selection and arrangement of the latest commercial illuminants.

Impressions of the West 1898—1909 The Western trip which I made in September included several places which I visited eleven years ago. Many contrasts were therefore apparent. As everybody knows, both the West and electric transmission have made some prodigious advances during the past decade. But when one actually sees these changes, they are far more impressive than generalities and statistics.

While at Salt Lake City eleven years ago, I visited three water power plants which were sending power to the city. About 3 000 kilowatts were supplied; the electrical equipments of the stations were already provided for double that amount; and the station buildings were laid out for still more generators, although the water available during that summer was just about equal to the power supplied. More than this, a gentleman who had made a careful study of the power situation said that he could not find a market for more than about 3 300 kilowatts in and about Salt Lake City.

The opening up of new copper industries has been the fundamental element in changing the situation. The local railway and lighting company now draws power from nine water power plants and has three steam plants. At times all twelve are operated in multiple. A part of the water power is purchased from the Telluride Power Transmission Company, which supplies the larger portion of its power to various mines and smelters. One new power house with two generators, each of which could deliver all the power used in the Salt Lake district eleven years ago, is just being put into operation.

At San Francisco there were no incoming transmission lines eleven years ago, while at present there is a network covering hundreds of miles, to which innumerable water power plants are contributing. I had the opportunity to visit only one of these plants; that of the Great Western Power Company on the line of the new transcontinental road, the Western Pacific. This power house is very impressive, the cement buildings and the generous provision for the bus-bars and high tension circuits indicate the new order of substantial construction which is placing electric generation and transmission on a new basis as to continuity of service. This plant has certain historic settings as it utilizes a tunnel some three miles long into which were poured several millions of dollars of the profits from a commonly advertised patent medicine. The purpose was to short-circuit the river at a great bend, so that 17 miles of river bottom would be available for gold-dredging. In answer to inquiries made of several people, I learned that the project was a failure, because the bottom of the river was full of boulders which made it impracticable to work out the gold although there is plenty of it in the fine gravel and sand; also that there is not enough gold in the river to make it pay; also that the tunnel was left so rough inside that it would not drain all the water from the river. All explanations agreed, however, that the old project had not been successful and that the tunnel was now, for the first time, after some modification and reconstruction, adapted to a useful purpose, in giving a head of something over 400 feet of water to the pipe lines which descend from its lower end to the power house. There are now four 10 000 kilowatt generators, which are to be followed by as many more. A dam about 100 feet high will be built across the river at the intake, giving an additional head. I was told that further up this little branch of the Feather River—the map shows many such streams—there is sufficient head to give 500 000 horse-power.

Although a network of transmission lines connects a very large number of water power plants with San Francisco and the district surrounding it, yet the growth of the market for power has increased more rapidly than the supply. In fact, the conditions are quite similar to those in the Salt Lake district. I was told that when the new Independent Company's plant was put in some six or eight years ago, it was predicted that the 6 000 or 7 000 kilowatts provided would not find a market. At present there is between 75 000 and 100 000 kilowatts of engine-driven apparatus in San Francisco, supplementing what is being received over the transmission lines, and

there is still insufficient power. Additional steam plants are now under construction.

We in the East often wonder whether new water power plants are not the outcome of the over-enthusiastic promoter. It seems that, in the principal districts at least, water power development is not keeping pace with the demand for power.

On my former visit to Seattle, plans were being made for the Snoqualmie Falls plant. I visited the picturesque falls on the same day that the drill broke through between the excavations for the intake and those for the tail race. On my present visit I descended through the shaft for some 250 feet to the power house excavated in the rock, and then walked through the tail race tunnel and looked up at the dry falls. The original dynamo capacity has been nearly doubled. The insulators are being changed so that the original 30 000 volts can be doubled. Seattle, instead of looking forward to its first transmission line, is now fed from numerous power plants and is veritably an electric city. I understand that there is only one isolated plant of any consequence in the whole city.

A visit to Portland also recalls the past. I well remember the respect and awe we all had at the factory, in days when our thoughts and experience did not go much beyond 1 000 volts, when orders were received for alternators to give 4 000 volts and transformers to reduce from 3 200 to 1 000 volts, to be installed, respectively, at the Willamette Falls and at Portland, twelve miles away. The dynamos were single-phase machines and had one T-shaped tooth per pole, and served their purpose for many years. Now Portland is well modernized electrically in its lighting, street railway and interurban service, although one does see a rather odd sight when a steam locomotive drags its little suburban passenger train through one of the principal streets of the city.

A general attitude towards electricity, which is becoming common everywhere, is manifest in Butte. I was in Butte five years ago, when electricity was on trial. The operators who were accustomed to making their power from steam were quite wary about adopting electricity and depending upon a power house a day's journey away. All this seems to have changed and the problem now is, how to apply the electric power in the best way. One plan now in favor is to drive the present air compressors by motors instead of engines and to use the air in the present steam hoist, and

for drilling and the like, by use of present appliances. This practical scheme has had much in its favor, although the electrical man cannot but regard it as an expedient, looking forward to the time when electricity will be directly applied to the ultimate service. One of the most impressive differences between electrical and other methods was in one of the mines (one afterwards visited by President Taft) in which induction motors are driving pumps lifting water some 1 200 feet. There are three pumps in one room, requiring an aggregate of about 800 horse-power. Each motor has a single switch for starting. After looking over these simple and compact pumps, I was taken into an adjoining room of four or five times the area and containing the discarded steam pumps. It was an intricate mass of heavy pipes and large machinery. The steam was brought from the boilers nearly a quarter of a mile above, and the pump room was said to have been so hot as to be almost unbearable. About four times as many men were required for the steam pumps as are necessary for the electric pumps. This object lesson on the difference between steam operation and electric operation was about as impressive as the change from steam locomotives to electric locomotives in tunnel service.

I gave some notes last month regarding the electric locomotives in the Cascade Tunnel and recounted the story of others regarding steam locomotives in the tunnel. Later, on another road, I was in the rear locomotive of a long freight train which had two locomotives at the front and two near the other end. When we approached the tunnel the engineer closed the windows of the cab and drew the curtains. He placed a canvas bag over my head and kindly gave me his place, in the most protected portion of the cab. Before we were through the tunnel, the air and gas in the sack were getting so hot that I decided I would try to hold my breath until we got to the good air again. The steam began to scald the backs of my hands and I put them under cover. This tunnel was only about 800 feet long. I have no desire to test the conditions in a 13 000-foot tunnel up a two percent grade on a steam locomotive. A Pullman car is bad enough.

A traveler is expected to give some general observations indicating the present trend of affairs. Pessimists are very scarce in the West, or they kept very quiet. There is a general sentiment of optimism of the constructive kind. Conditions are good and everybody expects to make them better. San Francisco has met the results of the fire (they are very careful to call it a fire and not an

earthquake) with amazing rapidity; in fact, one who was in San Francisco so long ago as to have only a general recollection of the buildings, scarcely realizes in going about Market street and the business portion of the city that there have been any great changes. When looking from the top of a high building it is hard to realize that the great area which is pointed out and is now covered with buildings has been built up out of the ruins of a few years ago.

In transmission, both the practice and the ideas of engineers seem to point definitely towards several things: A transmission line with steel towers and long spans; under-hung insulators; overhead grounded wires for lightning protection, and electrolytic lightning arresters. The more I see of the under-hung insulator, the more excellent do its features appear, and in service the line presents a most satisfying appearance from the standpoint of electric and mechanical adequacy.

There is much interest and inquiry regarding oil switches and oil circuit breakers for high tension lines and automatic relays for cutting out defective lines. The problem a few years ago was to handle a transmission line; now it is to handle a system with many lines.   CHAS. F. SCOTT

**Some
Early
Railway
Experiences**

The article on "Parallel Operation of Machines with Series Fields," by Mr. H. L. Beach, which appears in the present issue, recalls to the writer some of his early experiences in connection with electric railways. Just nineteen years ago this month the writer entered the employ of what was then the second largest electric street railway system in the country. The motor equipments of this road consisted at that time of about three hundred cars, with two motors per car. All of the motors were of the double reduction gear type and rated at twenty-five horse-power each. Upon what this rating was based the writer was never able to determine. They were all bi-polar machines and practically all of them were controlled by field commutation. There were three separate coils on each pole, each coil being wound with wire of different size to give different resistances and the coils arranged all in series at the start, which made the total resistance sufficient to limit the current to give easy acceleration. The motors were connected permanently in parallel and, as no external resistance was used, all of the loss incident to accelerating the car from stand-still

to full-speed was taken up by the fields. This was compensated for to some extent by the high magnetic saturation in the motor due to the large number of turns on the field. However, the heating was excessive, with the result that the fields rapidly burned out. The armatures of these motors were also wound with very small wire and burnouts were very common. These electrical defects, taken in connection with a weak mechanical design, gave a motive power that was, to say the least, very feeble.

The controllers used on these cars for manipulating the field connections consisted of drums of wood, fitted with sheet brass contacts. As there were no extraneous means for suppressing the arc formed in breaking the circuit, the controllers were rapidly worn out. The fields were permanently connected in parallel as were the armatures and the motors were reversed by reversing the armature connections. With this arrangement the current in the fields would divide between the two motors in direct proportion to the ohmic resistances, while the current would divide between the two armatures in direct proportion to their counter electro-motive forces. Since the armatures were geared to axles having wheels of the same size and, consequently, had to rotate at the same speed, and as the counter electro-motive force in each motor was proportional to the magnetic flux, the magnetic flux through the armatures with a given current in the field windings would vary with the reluctance of the magnetic circuit. As there are a great many things that affect the reluctance of a magnetic circuit, such as the quality of the material and the total air-gap of the magnetic circuit, it is evident that it was almost impossible to maintain an equality between the two motors. When the motors were received from the factory they were marked in pairs, these pairs to be mounted on the same car. It is probable that they were selected and paired off by testing them for speed with given current and voltage. This arrangement gave fairly satisfactory operation while the motors were new and the pairs were kept together. The method of control, however, was so disastrous to the motors that it was necessary to tear them apart continually to renew the field coils. This taking apart and putting together of the motors soon disarranged their magnetic circuits so that another difficulty, more serious even than the field trouble, was soon in evidence. An increased number of armature burn-outs seemed to indicate something inherently wrong with the motors and a series of tests was inaugurated to locate the trouble. Following up some observations that had been made, that one motor of the two on a

given car would spark very much worse at full speed than the other, the conclusion was drawn that they were unequally loaded. By placing an ammeter in circuit with each armature it was found that the load was very unequally divided between the two armatures, in fact it often occurred that one machine would be driving the other as a generator, carrying at times as much as double full-load current. Operating under these conditions, the machines rapidly burned out. During this time the equipment of the road was increased by the purchase of some single reduction motors, but as they were equipped with the same scheme for reversing, the troubles with these motors were equally great.

During the winter following the writer's connection with this street railway company it required two hundred men to make electrical repairs on three hundred car equipments. A considerable portion of these burn-outs was due to the bad arrangement of control, but a very much greater portion was due to the unequal loading of the two machines owing to the system of connections.

In looking back at the operation and the method of handling electric railway equipments at that time, some peculiar features are very prominent. One of these, that leaves quite an impression on the writer's memory, is the fact that the power house attendant was very severely criticized if he allowed the voltage to vary outside the limits of 500 volts as the minimum and 505 volts as the maximum, it being generally understood that if the voltage got outside of these limits it would be very disastrous to the motor equipment. This seems especially peculiar as, when the writer left the road some three years later, these same motor equipments were operating at a power house voltage of 650 volts. They were, however, the same motor equipments only in that the same magnetic circuits were used. All of the windings and the mechanical structure of the motors had been entirely changed.

In thinking over these early experiences and comparing them with the cases mentioned in Mr. Beach's article, the thought naturally comes that the electrical industry is expanding with such rapidity that it is impossible to avoid repeating similar errors, a great many of which are difficult to anticipate and are only brought to light by the iron-handed teacher—experience.

<div align="right">William Cooper</div>

FUNDAMENTAL REASONS FOR THE USE
OF ELECTRICITY *

[CHAS. F. SCOTT

I N reviewing the possible subjects which might be presented with
interest to a general meeting of electrical men, one is impressed
by the wide range of topics which might be selected and also
by the specialized character of most of them. Many subjects which
were foremost a few years ago have taken a secondary place as they
have passed from the field of general engineering discussion into
that of practical operation. The design and characteristics of gen-
erators and of ordinary switchboard apparatus, the construc-
tion and connection of transformers, the construction employed
and the ordinary phenomena occurring in long distance trans-
mission have lost their novelty and have become the subjects for
discussion at experience meetings among those who are especially
interested in them.

This does not mean stagnation; in every branch the manufac-
turer and the operator are alert; improvements in apparatus and
methods are continuous; but the lines of development are fairly
definite, advancement is accepted as the normal condition, and mat-
ters relating to fundamental apparatus and plant operation have
taken their place in the category of established practice.

THE POSSIBLE FIELDS OF ELECTRIC SERVICE

Interest now centers along certain other lines. We are now con-
cerned with the use rather than the generation of elecrticity. The
active problems to-day are those which pertain to the application of
electric current.

To gain a general view of the situation we may, instead of
enumerating specific uses, consider the possible field. Electricity
supplies light, heat and power. Now nearly every activity in domes-
tic life, in agriculture, mining, manufacture and transportation in-
volves energy in one of these three forms. By old-time methods
light was supplied by candles, oil or gas; heat was derived from fuel

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*From a paper entitled "The Trend in Electrical Development," read be-
fore the joint convention, N.-W. Electric Light & Power Association
and Seattle Section, A. I. E. E., Seattle, September 7, 1909.

—wood or coal, oil or gas; power was produced by means of animals, by steam engines or water wheels. In nearly every case, the same result can be produced by electricity. Light, heat and power can be produced by a single agent instead of a dozen. This is the scientific possibility. Make a list of the things electricity cannot do, of the instances in which it cannot produce the needed light or heat or power, and see how short the list is, and note also how much better results are obtained, all the way from Christmas tree lights to searchlights, from the flatiron to the steel furnace, from desk fans to hoists and express trains. Electricity is not merely a convenient means of doing a few things; it is capable of universal service, Such, then, is the possible field from the scientific standpoint; the immediate problems are to determine what is practicable from the engineering standpoint and what is economical from the commercial standpoint.

In taking a perspective view of the present situation, one is impressed with the sudden and radical extensions which have taken place in the use of current in a very few years. In illumination the simple 16 c-p carbon lamp, and the enclosed arc lamp, have given place to new types, which in effiicency, length of life and quality of light have realized ideals which were beyond all reasonable expectations. The application of the electric motor to general domestic, commercial, industrial, mining and railway service marks an epoch in the history of power. Electric heating, which is still regarded as a novelty and a curiosity, is being applied to over one thousand different kinds of service.

CONDITIONS UNDERLYING THE APPLICATION OF ELECTRICITY

What are some of the the conditions which have produced this sudden and widespread activity, and which underlie future development?

First, is the fact that we are all power users. The fundamental thing which underlies the progress of the past century is the steam engine. The underlying factor in modern industry is the power-driven machine; consequently there is a ready field for the motor, which can apply power far more advantageously than the engine, and which can supply power for operations for which the engine is not applicable.

Second, is the evolution of the electrical system for supplying power. The work of designers, manufacturers and operators in

developing the apparatus and methods for generating, transmitting and distributing electric power makes the electric current available, as it has never been before.

Third, there is a general industrial activity which is alert to adopt new and improved methods and a readiness to secure whatever contributes to comfort and convenience, all of which summarize themselves in a spirit of progress.

Granting these several conditions, namely, that there is an unlimited field for the use of electricity; that electric power is ready and available; and that there is a readiness to accept that which is good, the problem of electrical extension is to determine the best methods of application and to show that electricity can make good. Most people, particularly those to whom electricity is still a curiosity or a novelty, must be shown how to apply the electric current, and why it is worth while. The problem is not wholly engineering, nor is it purely commercial, but it combines the two. It is not wholly electrical, nor is it entirely mechanical and industrial, but the motor and the work which it is to do must be mutually adapted one to the other.

METHODS AND EFFECTS OF USING ELECTRICITY

In the use of electric current, whether for lighting, for power or for heating, there are several underlying methods or principles which appear when the conditions are analyzed.

1—The electric current is often directly applied to replace the former agent. Incandescent lamps can be place on the same fixture and in the same position as gas jets. The electric motor can be belted to a line shaft.

2—Electricity can usually do more and do it better. Old methods may have been devised not because they were inherently advantageous, but because they were necessary. Thus electric lamps can be hung down, whereas the old gas jets must stand up; electric motors can be made in small sizes and applied directly to the machines they are to drive, which is impracticable with the steam engine, and electric heating can be applied within the cooking vessel, which is impossible when fuel is used. These simple illustrations apply to the whole field of electrical application. It is usually an easy matter to make electricity do just what was done before, whereas better results can be obtained by changes in methods which electricity makes possible.

In operating machine tools, for example, the electric motor not

only supplies power which might be taken from an engine, but it can be directly applied to the tool and can run at a speed best suited to the work to be done, an advantage which often far outweighs any saving or convenience in merely supplying the power. It is this facility of controlling the speed of the motor in supplying electric power, and of controlling the temperature in electric heating which constitute the really great advantage. Considerations of this kind are of vital importance, all the way from the steel mill to the sewing machine.

3—Electricity can be used where there is no other means at hand. It is the only practical means of producing power in small units, such as is necessary for the operation of a desk fan, a sewing machine, or a hundred other common devices in the home, the office, the store, the hotel or the shop. In these small units electricity replaces the most expensive source of power, the human muscle. The interurban and underground electric railway, the motor-driven pump for irrigation, the remote control of motors, are other instances in which electricity does what was not practical by other means.

4—The indirect and sometimes the unexpected advantages resulting from the use of electricity are sometimes of even greater importance than those which were directly sought. For example, an electrically driven machine may have in circuit a graphic recording wattmeter making a continuous record of the power used by the machine. Such a record shows the length of time the machine is idle. An analysis of the causes of loss of time may lead to some simple change in conditions which will result in increased output. Again, the length of time and the amount of power used in the successive operations, which are recorded, may indicate whether it is operating at its maximum rate. This is a check upon the manner of doing the work and upon the general surrounding conditions which has in several cases shown how to increase output and reduce operating cost sufficiently to more than pay for the cost of the electric power.

My attention has been called to the application of the wattmeter in a factory in connection with electric heating, such as by flatirons, in which the amount of power used is an indication of the amount of work done. The results show what is termed a fatigue factor; work starts briskly in the morning, but decreases till noon. Immediately after noon the rate is high, but it falls off much more rapidly in the afternoon and is lowest just before quitting time. Such a fatigue factor has an interesting bearing on the relative ef-

ficiency of the eight and the ten-hour day. It is also interesting to surmise how much more rapidly the fatigue factor would fall if gas were used and the air were hot and vile.

The important incidental advantages of the electric drive in the steel mill are shown in a paper read before the last convention of the American Institute of Electrical Engineers, by Mr. Friedlander. The paper purports to give a simple account of several years' operation of a direct-current motor driving a pair of rolls, but there is scarcely a page which does not show wherein the motors are doing something which the engines could not do. Mr. Friedlander points out that the rolling mill drive has taught how to get the best relation among rotating masses, speed, time and horsepower. It has helped the roll designer to calibrate the rolls in such a manner that the power characteristics for all the passes are uniform, thereby avoiding high power peaks, decreasing the size of the prime-mover, and reducing first cost and fuel consumption. The wattmeter warns the roller when bearings or rolls become tight and hot, or steel is causing excessive friction in the passage, thereby guarding against damage to the rolls and bearings. The meter indicates that lower heat, greater elongation and, especially, change of profile in different directions increase the power required at the rolls much more rapidly than do chemical hardness, high tensile strength or large draughts. After analyzing the conditions in reciprocating engines for this work, he finds that the characteristics of the electric motor are much better. A little further on he says heavy reciprocating engines cannot run at such high speed and must be connected to the rolls by means of gears, ropes or belts. Again, the motor gives accurate information as to the exact power requirements for rolling steel, whereas indicator diagrams taken on reciprocating engines doing similar work were misleading. Further on he says that with the use of electric motors in place of reciprocating engines the problem of reversing rolls becomes much simpler in regard to manipulation, fuel consumption and cost of maintenance.

Now all of these more or less indirect things are points of superiority which the electric drive has over the steam drive. They show a reaction or interaction between the motor and the mill which indicates how really important and vital is the electric system beyond the mere ability of the motor to drive a pinion, a pulley or a shaft.

METHODS OF APPLYING ELECTRICITY EFFECTIVELY

A review of the general conditions shows, therefore, that the possible field for electrical service is unlimited, that apparatus is

available for producing electric power, that there is a readiness to adopt superior methods, and also that electricity can generally be used as an economical substitute for other agents, that it can accomplish better results, that it can develop new fields and that it is accompanied by indirect or incidental advantages which are of great value.

These being the groundwork on which we are to base our electrical development, a number of points follow as corollaries relating to the general situation and to methods of applying electricity effectively, from both the engineering and commercial point of view.

a—The electrical apparatus and the methods of application must be intelligently chosen. Increasing discrimination is being exercised in applying electricity. The 16 candle-power lamp and the belted motor of a few years ago did not receive much expert direction. But there are now illuminating engineers, with a society and a monthly paper, dealing with methods of effective illumination, and there are commercial engineers directing the application of motors, who study methods and gather data. A typical evolution is found in the machine shop. At first the motor was a convenient method of driving a line shaft. Next it was found more convenient and better to apply the motor directly to the tool, and then note what happened. The tool began to change, it could be run faster and varied in speed, it could be made stronger, it could operate the new high speed tool steels, and the designers of machine tools got together with the designers of electric motors and worked to harmonize their machines in characteristics and mechanical form, and they made one unit of the two. As the result the electric drive is put in the machine shop, not merely because it can furnish power a little cheaper but because the machine tool can be made to do so much more and can do it better and cheaper.

The need of specific adaptation has been recognized by the manufacturers of electrical apparatus. Instead of a few sizes of motors running at one or two definite speeds, they now offer a great variety of motors having different mechanical forms and speed characteristics specifically adapting them to the work which they are to do. A tremendous amount of work has been done in fitting the motor to other apparatus, all the way from music boxes and vacuum cleaners to pumps and cranes. Sometimes a specially designed motor is required and modifications are often made in the apparatus to be driven. The object and the end is effective adaptation. In electric heating devices the same activity is found. Special heating appli-

ances are available for hundreds of purposes and in other cases standard or special heating units are made, which can be readily applied to replace gas or steam in endless applications.

All of this indicates the trend toward specific adaptation. While this principle is acted on by the electric manufacturers and by makers of many other kinds of machinery which employ electric motors or heaters, it is only beginning to be recognized and acted upon by the general public in applying the apparatus.

b—A careful study should be made of the operation which is to be performed. Sometimes the conditions are simple; at other times they are complex. Often the general arrangement of a mill or factory may be made entirely different if many motors instead of a single engine supply the power, or some simple difference in the form or position of motor-driven tools may greatly facilitate the handling of material or the convenience of operation. In some instances where a constant and definite speed is important the actual speed with engine drive has been below the maximum on account of variable belt slippage, whereas the steady, maximum speed secured by motor drive has resulted in an increased output of uniform quality— a result which alone justified the electrical equipment. In another case the removal of belts and overhead bearings from which oil was liable to drop on the expensive woven product has resulted in great saving. Instances might be multiplied to show how large are the indirect and in a sense the incidental features, which are apt to be overlooked.

COST OF POWER

c—The cost of power is usually the first item which is considered. Sometimes it is the controlling factor, but often it is quite secondary as compared with other economies in electric methods. To the power user the cost problem is, in some cases, a double one; first, the relative cost of electric power and of steam power, and second, the relative cost of purchased power and of power produced in an isolated plant. The solution of the problem is not as simple as is its statement. Many of the factors which enter into the cost of power are quite difficult to determine. In a steam-driven factory or mill the total annual cost of power may be quite definitely known, but the cost per horse-power-hour is quite a different matter. The latter can be quickly calculated by assuming that the engine develops its rated output ten hours a day. But usually it does not, its load is fluctuating, the load-factor is low, much of the power developed does not pass beyond the belts and shafting. It is easy to overestimate the

actual useful power required, which determines the amount of electric power needed to replace the engine. A man who has a 100 horse-power engine calculates that electric power at $60 a year would cost $6,000; but the average load may not be over 30 or 40 horse-power, and is sometimes much less.

Furthermore, the subdivision of a motor driven factory permits the shafting and machinery in parts which are not needed to be idle. Simple and obvious as these matters may be, yet they are apt to be overlooked, although they may be the really determining factors in making correct cost comparisons. The results of actual investigations have shown a surprisingly large number of cases in which cheaper power is obtained by the substitution of motors operated by central station power than from steam engines and even gas engines operated by natural gas.

d—The total cost of operation by the old and by the electric methods is one which involves far more than the first cost of apparatus and the cost of power. In general, the interest on the first cost of motors is small compared with the cost of current which they consume, and in nearly all ordinary applications in which labor is involved the cost of power is low compared with the cost of labor. Hence the prime object should be to increase the output of labor. Whatever conduces to rapidity, reliability or continuity, so as to reduce the labor cost by even a small fraction, justifies a considerable increase in the cost of power. It may increase the rate of doing the work which the man directs, it may reduce the number of workmen required, it may by better illumination or ventilation in the mine, the factory, the office or the kitchen, increase the efficiency of the expensive human machine. If better light will enable the mechanic or the miner to do more work, or prevent the mistakes of a bookkeeper or a sewing girl, if electric cookers and washing machines and irons and sweepers enable one maid in the house to do what two did before, of what consequence is a few cents in the cost of current? But aside from the labor element almost every application of electricity is a working example of its indirect advantage in convenience and economy. What would appear less promising than the running of a paper mill electrically instead of driving it direct from water wheels? And yet the electrical system is justifying itself because of simplicity, flexibility, convenience, ease of control and economy. What could be less promising than electric drive for a sawmill? And yet electric power is in some cases purchased from a central station and in other cases it

is made in an isolated plant with satisfactory results from the stand-point of cost. If the substitution of a motor for a logging engine can prevent a forest fire now and then, questions of convenience and cost are of trifling consequence. If an electric locomotive in a mountain tunnel increases traffic capacity, removes congestion and delays, and does away with smoke and deadly gases, it matters little whether or not the saving in coal is equal to the cost of electric power.

And yet it is a common habit to lay great stress on the cost of current and to overlook or minimize other things. The relative cost of the electricity required for replacing a gas light or a steam engine or a gas heater, is to many people the controlling factor. A good example is found in a recent report on the "Adoption of Electrical Heat for Industrial Purposes" read before the last convention of the National Electric Light Association. The report is an admirable presentation of the subject, full of information and suggestion. An account is given of results with the use of electric soldering irons. In the making of tin lanterns each man had produced by the gasoline heated soldering coppers 225 per day, and by the electric soldering irons each produced 300. The leaking seams were reduced from one in twenty to one in 200. The cost for the electric current was found to be less than one-half of that for gasoline. In other cases the cost of heating a soldering iron was about 19.5 cents per day by gas and 12.5 cents by electric current. About a page of the report deals with the relative cost of the electric current and less than two lines are devoted to the simple statement that the output is increased 33 percent, then there is a summary as follows:

"These reports demonstrate that the electrically self-heated tools operate at an appreciably lower cost than it is possible for furnace heated irons, not taking into consideration the increase of working efficiency, absence of noxious fumes and heat, low installation expense, extreme compactness, portability, and reliable promptitude of action."

This sentence shows the importance which an expert committee seems to place upon cost of power, rather than upon other things.

If working efficiency, absence of noxious fumes, compactness and reliability are worth while, why not emphasize them and forget about the seven cents saving? This is a case where electricity at any reasonable price could compete with free gas. This instance illustrates the general tendency to put electrical operation on a par with other methods by making the fundamental comparison one of cost. Without minimizing the importance of the cost of power, which in

some cases is the controlling factor, it must be recognized that this kind of comparison is the most narrow and limited, and it neglects what are often the greatest reasons for using electric power.

NEW FIELDS FOR CENTRAL STATION ACTIVITY

e—-The increased use of electricity is the vital problem before the central station. One of the first items to consider is that of rates. A fair rate per kilowatt-hour when the whole income is derived from an evening lighting load is too high for a day load. A fair rate for a steady load of 10 hours or 24 hours is unnecessarily low for an intermittent load. The rate problem is as intricate and complex as it is vital, alike to users and producers of electric power, and it is receiving careful attention and varied solutions by central station managers. In general lower rates lead to increased consumption of power which in turn lowers the cost of furnishing power. Rates and extension of service are part of one problem—the complex engineering and commercial problem which some central stations are solving by new schedules of rates and systematic efforts for new business. Advertising and educational campaigns are being conducted by electric talks in the newspapers, by street car advertising, by house to house canvass and by the introduction of apparatus on trial.

The expert knowledge which is often essential to success must be supplied by experts. Moreover, conditions are changing. In our growing country with its big enterprises and its cheap materials, the problem has been to make and to do at any cost; now we must look to efficiency and refinement of methods. The large manufacturing companies have specialists for studying methods and supplying data and advice to central stations and power users. Just as they are gaining the confidence of their clients so the central station should have proper advisers for its customers. Good salesmanship is not sufficient. The large electric manufacturing companies have found that the sales department as well as the designing department must contain men who are good engineers. The application as well as the generation of central station power must be upon an engineering basis.

Where power is already produced in an isolated plant which the central station wants to supersede, the situation often requires an engineering diagnosis, and an educational treatment. One manager who has made a speciality of substituting motors, says that he

follows a friendly policy, the subject is taken up in successive stages, information as to the operation of other plants is furnished to the prospective purchaser of power, the conditions in his plant are investigated, his engine is indicated, the time during which individual parts of the plant are running is observed and a full report is made. Sometimes a year or two has been necessary for producing the desired result. Sales work of this kind requires different methods from those formerly used in making contracts for incandescent lighting. In some central stations the installation engineer is becoming an important member of the force. He studies the customers' conditions and needs. He advises regarding the lighting of stores and factories and residences, and consults with architects regarding the location of lights in new buildings. He investigates and advises regarding the use of motors and the application of heating appliances. He acts for the interests of those who purchase as well as those who supply electricity and in the long run he serves both best when his first aim is to make the electric service satisfactory and profitable to the consumer. Fortunately, the use of electricity is like leaven, it increases naturally. Small installations of motors are followed by larger ones, on account of economy in power, the gain in general flexibility or in convenience of control. In the home the same rule applies. A friend recently remarked that a short time ago he had used electric light in connection with gas but now he has no need of gas. He has an electric iron, a motor on the sewing machine, an electric toaster and a motor-driven vacuum cleaner, and he purposes to arrange to shift belts so that the motor can drive either the vacuum cleaner or the washing machine. Similar illustrations are found at every hand, showing how automatic is the growth of the habit of electric living.

ELECTRIC HEATING

f—Electric heating is in very much the same situation now as was the the motor ten years ago. It has been regarded as something of a fad or a novelty and is just now being taken up in a general and serious way. Sometimes motors are used because they can apply power conveniently and effectively, and sometimes because they are a cheap source of power in large amounts. Likewise electric heating may be divided for convenience into two general classes, that in which quality is all important and that in which quantity is paramount. The quality class comprises applications where convenience,

ease of control, absence of fire risk and of gases, are involved and includes most of the ordinary domestic and manufacturing uses. The other class, in which quantity of heat is involved, appertains to the heating of rooms or buildings or of large volumes of water, or ore or metal. In the first the amount of power is small; in the second it may be very considerable. The first can use current at a fair price; the second is usually economical only at a very low price for current.

It is astonishing to find how very many kinds of heating applications there are, and a very little consideration shows what innumerable uses for current will come with the general introduction of heating appliances, which are already on the market. Heat in quantity will find many acceptable applications particularly where it can be used or stored during the hours of the day when the current could be employed for no other purpose. The use of heat on a large scale in the electric furnace is a rapidly developing application, which gives great promise of important uses in handling metals, particularly in the manufacture of steel. The general heating problem is one of great promise from all standpoints. It is one which needs sound engineering guidance and it promises to react upon the load factor and the power rates of the central station.

APPLIED ELECTRICITY AND THE ELECTRICAL ENGINEER

g—The general problem of the application of electricity is comprehensive. It involves the design of apparatus for specific ends, which requires that the designer know what his apparatus is to do. On the other hand, it calls for a re-adjustment of appliances and of methods, in the home and in the work-shop, which will adapt them to the new conditions which electricity supplies. It involves commercial relations between those who supply power and those who use it. It reacts upon central station load factors and costs and rates. It brings the central station into vital relation with the community. Instead of serving a single commodity for a few hours in the evening, it furnishes the energy which cooks the meals and sweeps the floors, which runs the cars and the elevators, which operates the grinders in the meat shop and the grocery, the mangles in the laundry, which heats the irons of the tailors and the chocolate of the candy maker, which runs the saw and the lathe and the planer, which serves the miner and irrigates waste lands. All this means a new relation between the electrical engineer and the community.

The electrical engineer is naturally a missionary. He has pushed forward, conquering many fields in which he was but little welcome. This is noticeable on a large scale in the steel industry. It is not many years since the motors in the steel mill were regarded as suited only to run small cranes and the like, and not for the large and serious operations of the mill, but now in the greatest steel plant electricity is supreme, even the steam engine is no more. The electric system has transformed the method of producing power as well as the way of transmitting and using it, and the electrical engineer, who was not long ago operating a few arc lamps and repairing crane motors, is now brought to a most responsible position, having much to do with the design of the mill as well as its operation. What has been established in the steel mill must be accomplished in the community. Electricity must emerge from a convenient means of doing a few things into the central operating system.

The output of coal—the power producer—has been a true measure of progress. Electricity is showing us how to transmit and apply power. We are just entering a new era in the use of power— of universally applied electric power. The fundamental conditions are auspicious, the possibilities are unlimited, and the outcome will be determined very largely by the ability with which we electrical men meet the opportunities which lie before us.

STANDARD RELATIONS OF LIGHT DISTRIBUTION*

ARTHUR J. SWEET

I N the opening-up of a new land to civilization, the first bold-hearted explorers penetrate to the very heart of the country, guiding their difficult way through tangled forests, across morass and river and mountain, by the help of the compass and by their knowledge of the laws which govern the flow of rivers, the contour of the earth's surface, the growth of flora and fauna. One explorer starts from a certain point on the sea coast and reaches his goal by a westerly course. A second starts from another point on the coast and reaches the same goal by a northwesterly course. A third sets out from the known country to the south and, making his way northward, reaches at last the same spot that the other two have set foot upon. Each explorer, at a heavy cost of effort and time, makes his own pathway, and after months brings back to the civilized world a small and dearly-bought measure of the gold or the gems that lie hidden in the heart of the country.

The new land is a land of great possibilities of wealth and commerce. As fruit of the explorers' toil, the first rough maps are made. A few main highways are laid out from these maps, and the roads are built. Over the roads go the merchants. Few of them know all the precautions to be taken in the use of the compass. Still less of them understand the geographic laws that were the guide of the early explorers. But they know that the road was laid out by those who did understand these things, and that it leads them whither they would go. And they go easily and easily return with large measure of the country's wealth for the use and enjoyment of the world at large.

The opening-up of a new field of science is wonderfully similar to the opening-up of a new land. The new science, like the new land, first attracts men of the explorer type. We call these explorers specialists. From many a different starting point in the known lands of adjacent sciences these specialists enter the unknown country of the new science. Guided by the compass of a definite aim and by their knowledge of the geography, so to speak, of the old sciences with which they are familiar, our specialists find their

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*A paper read before the annual convention of the Illuminating Engineering Society, September, 1909,

way to the heart of the new science through unmapped stretches of new physical relations, through tangled forests of technical difficulties, over the mountains of seeming impossibilities. Each man at heavy cost of time and effort treads out his own separate pathway, and by and by returns with his bit of gold,—the illumination design, perhaps, for a certain room of a certain building in a certain city.

The world will have but little good of the wealth that lies hidden in a new country so long as it must depend on men of the explorer type to bring that wealth forth. Highways must be built— roads that the merchant or miner, who is no path-finder, can follow.

The world will have but little good of the benefits that lie hidden in a new science so long as it must depend on men of the specialist type to bring those potential benefits forth into concrete accomplishment. Highways must be built—highways that, in our own new science, for instance, the architect and the electrical engineer can follow; nay, more, highways for the use, most of all, of the illuminating engineer himself, that he may easily reach the wealth of the new science and bring it forth in large measure. For if truth be told, there are to-day many illuminating engineers, men more of the miner than of the explorer type, who are floundering about most woefully in the morasses of their science, making but slow and zig-zag progress, but who, if a highway were furnished them, would serve the world most usefully.

The highways of a science are the standard relations which, once established, can be applied to concrete problems in rule-of-thumb fashion without referring anew each time to the laws upon which they depend. These standard relations are sometimes expressed by formulae, sometimes graphically by curves, sometimes in tabular fashion. Among the highways of electrical engineering, for instance, are the various tables of relations between cross-section of conductor and safe current-carrying capacity. Ohm's law is itself a great natural highway, like the valley whose level floor becomes a road as soon as the hand of man has set up the guide-posts upon it.

The science of illuminating engineering has not made in the past year the record for concrete accomplishment that many of us had hoped it would. I believe the reason to be that, while the main lines of exploration have been accomplished, we have scarcely commenced at road building. Indeed, ignoring a few disconnected stretches of unimportant side roads, we have builded but one por-

tion of the main highway. I refer to the formula developed by Messrs. Lansingh and Cravath.

Watts per sq. ft. = foot-candle intensity × constant from table.

That formula is a magnificent example of the sort of work of which illuminating engineering stands to-day in most pressing need. I ask you to join with me in analyzing the problem of light distribution, in attempting to establish some standard relations of light distribution which may serve to greatly simplify the problem of illumination design. As we proceed, you must remember that we are engaged, not in glorious exploration, but in the humbler though not less useful work of road building. When we finish, if we are successful, I am far more concerned that each one of you remember that we have built a road, a road for future usefulness, than that you should recall each turning and grade and shape of the road.

The complex problem of illumination design can be split up into a number of subordinate problems—the problems of intensity, of distribution, of diffusion and the like.
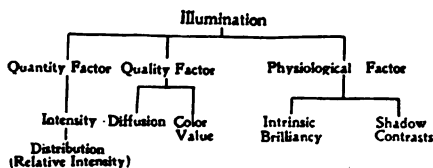
FIG. I—FACTORS INVOLVED IN ILLUMINA-
TION PROBLEMS

In Fig. 1, intensity and distribution are linked together as the quantity factors in the problem of illumination. Distribution is simply the problem of relative intensities, of proportion of intensities at different points. Distribution is subordinate to intensity, yet one cannot in actual practice settle the question of intensity on the basis of average value, without regard to distribution. Diffusion and color value are grouped together as quality factors, though each is, of course, independent of the other. Intrinsic brilliancy and shadow contrasts are two factors which, though independent, are linked together as factors affecting the efficiency of the eye, the receiving apparatus.

The intensity of illumination required is not a fixed quantity, but is conditioned upon the intensity of illumination of other objects within the field of vision. Distribution, too, is an all-important factor, not merely in determining the quantity of illumination on the work, but also in determining the quantity of energy necessary to produce that illumination. Light in useless directions is largely wasted, due to low coefficients of diffuse reflection; excessive light on surfaces within the field of vision, as the walls of a room, decreases the

efficiency of the eye and makes necessary a higher intensity of illumination on the work.   Here we have before us the two-fold importance of distribution as the quantity factor in illumination.

If, now, we can establish standard relations between certain types of distribution and certain types of illumination problems, we shall tremendously simplify the problem of illumination design. We shall know that to get correct illumination results for a certain type of problem it will be absolutely necessary to get a certain type of distribution.   The clear-cut, definite knowledge of just what type of distribution is desired will not only help us, as designing engineers, to select that illuminant which most nearly gives this distribution, but it will also enable us to obtain on the market the correctly designed illuminant.   The bar to progress in the past has been that the highway has not been built,—that illuminating engineers, much less the commercial manufacturing interests, have not had always before them the clear-cut, definite picture of the standard relations that exist between certain types of light distribution and certain general classes of practical illumination problems.

Let us classify and analyze the problems that confront the designing illuminating engineer.   There is, first, a very large number of problems that classify as the illumination of a room from one light center* located in the center of the room.   The illumination of most residence rooms and small offices belongs to this class of problem.   Then there is a second class of problem, the illumination of interiors, generally large interiors, from light centers arranged on the basis of the square.   The illumination of large offices and stores belongs chiefly to this class of problem.   Finally there is a third class of problems in general illumination, the illumination of a long, narrow room by several light centers arranged in a line down the center of the room.   The illumination of most small stores belongs to this class of problem.

GENERAL ILLUMINATION FROM A SINGLE LIGHT CENTER

The relation between the illumination results sought and the

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*The term "light center" is used to designate the group of light units, one or many, carried on the same fixture.   The term "light unit" is used to designate the light source, as incandescent lamp, gas mantle, or the like, taken together with whatever reflector or distribution changing devices are used with it.   Several incandescent lamps used with one reflector would, of course, constitute a single light unit.   When similar light units of a group constituting a single light center are mounted with parallel and like directed axes, the distribution curve of the light center is for all practical purposes proportionately the same as the distribution curve of the light unit.

distribution required to produce those results depends upon:—

1—The size of the room, and

2—The height of the light center above the plane of reference. That is to say, for any given size of room and height of light center, we can easily calculate the distribution curve which will produce the desired illumination result.

It is obvious that any given distribution curve will give the same proportionate illumination results so long as the relation between the size of the room and the height of light center is kept constant. A given distribution curve, for instance, will give the same proportionate results in a room ten feet square with a four-foot height of light center as in a room twenty feet square with an eight-foot height. For, suppose one plots the illumination curve of

FIG. 2—TYPICAL FOOT-CANDLE CURVES
Room lighted from single light source.

the first case and then simply assigns double value to the co-ordinates; the angular relations are unchanged.

We can combine, therefore, the factors *1* and *2* and say that the distribution required to produce any given illumination result depends upon the relation between the size of room and the height of light center. Let us call this relation J. Then

$$J = \frac{\text{mean dimension of room}}{\text{height of light center above the plane of reference.}}$$

For any value of *J* there is a given distribution curve which will produce the desired illumination result.

Let us ask ourselves, What is this desired illumination result?

keeping closely in mind the practical problem, and remembering that we are dealing with residence rooms and small offices.

Over the central half of the room we want a uniform, even illumination. Near the walls, the intensity of illumination may drop to one-third its central value. On the walls themselves we desire only sufficient intensity to illuminate the wall furnishings; one-fifth the central intensity is amply sufficient for this. We must not forget the importance of avoiding brightly lighted walls which compel a higher intensity of illumination on the work; which, through absorption, are wasteful of light flux that might otherwise be directed to good use, and which offer the eye no place of rest when the eye seeks relief from the work.

The proper illumination, as described above, for the residence room and small office is shown in Fig. 2.
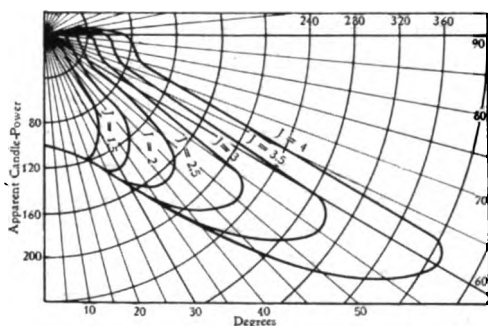
FIG. 3—TYPICAL LIGHT DISTRIBUTION CURVES
For various values of ratio *J*. Single light source.

Having analyzed our illumination problem and determined upon the proper illumination result to be obtained, it becomes a simple matter to compute the distribution curves which, for different values of *J*, will each give the same desired illumination, the illumination represented in Fig. 2. Typical distribution curves for such cases are shown in Fig. 3.

To obtain, therefore, the correct illumination results in that large number of problems that classify as a room lighted from a single light source, a type of distribution such as shown in Fig. 3 is required. It is a matter of secondary importance what particular value of *J* is chosen, provided it is within the limits of the extreme values shown. The average conditions of existing installations in the matter of mounting height would call for a value, J=3. The tendency of the future is towards greater mounting heights, corresponding to values of J=2 or 2.5.

Just a glance at the practical relations of our deductions thus far. Suppose the incandescent lamp, the Nernst lamp and the gas interests should each, with the co-operation of the reflector interests,

get out a light unit which for some definite value of *J* gave such distribution as shown in Fig. 3. In each standard package of such units would be included a little folder giving for varying sizes of room, the proper mounting height and the number of units required. The fixture manufacturers might, perhaps, be persuaded to design their fixtures with an easily adjustable part, so that the user could obtain the desired mounting height at little cost. The result of such enlightened handling of the situation by the commercial interests would be such an improvement in the illumination of our country as we specialists, treating each problem as a problem in itself, could never achieve. The specialist reaches the great problems—the church, the library, the theater—and that is his proper field. But if through our profession we are to serve our fellow-man in his everyday life, in his home and at his work, it must be with the help of the commercial interests in some such fashion as suggested above.

I believe the discussion thus far has made more clear to you the analogy of my introduction, the analogy of the building of highways in a new and undeveloped country. With the practical usefulness of our work thus clearly before us, we can take up with renewed interest the question of correct types of distribution from multiple light centers.

FIG. 4—MULTIPLE LIGHT CENTERS
Arranged on basis of the square.

GENERAL ILLUMINATION FROM MULTIPLE LIGHT CENTERS ARRANGED ON THE BASIS OF A SQUARE

This class of illumination problems is comprised chiefly of large interiors, usually large offices, stores, or factories.

The relation between the illumination results sought and the distribution required to produce them depends upon

1—The separation of the light centers; and

2—The height of the light center above the plane of reference. It does not depend to any important degree upon the size of the room, since the arrangement of light centers may be taken as subdividing the room into square areas, as shown in Fig. 4, and the solution for one of these areas solves the problem for the whole room.

Just as in the problem of general illumination from a single

light center, so here the two factors upon which distribution depends can be combined into one factor of relation. In other words, we can say that the particular distribution required to produce the desired illumination result depends upon the relation between the separation of the light centers and the height of the light centers above the plane of reference. Let us call this relation K. Then

$$K = \frac{\text{mean separation of the light centers}}{\text{height of light center above the plane of reference}}$$

For any value of K there is a given distribution curve which will produce the desired illumination result.

For the type of problem under consideration, we desire a uniform illumination of the area $A\ B\ C\ D$, Fig. 4. Outside of this area, as we approach the wall, the intensity should drop to one-half or one-third of its central value. On the walls the intensity of illumination should be low, for the reasons already noted.
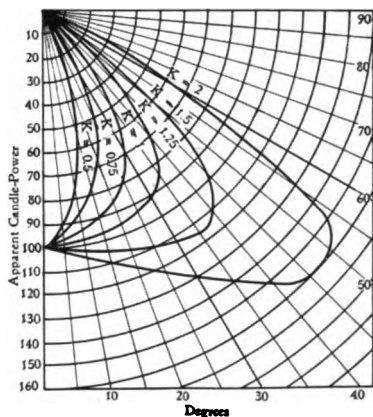
FIG. 5—TYPICAL LIGHT DISTRIBUTION
CURVES

For various values of ratio K.
Multiple light centers.

The derivation for the distribution curves for illumination from multiple units arranged on the basis of the square is based on the following analysis: For any value of K there is a certain *minimum* curve of distribution which will give uniform illumination. For suppose we have some given distribution curve which for a given value of K gives uniform illumination in the plane of reference. Now assume a second plane of reference parallel to the first and below it.

A moment's consideration will show that the illumination on the second plane of reference must be uniform, since the second plane is further from the light sources than the first and in the same direction, and since the illumination is obtained by diverging light beams; but relative to the second plane of reference K has a smaller value. Hence two values of K, or three values, or any number of values, can be assigned to the given distribution curve. Conversely, for any given value of K a large number of curves can be drawn which fulfill the condition of uniform illumination on the given plane of reference. Of these curves there must be a minimum, since uni-

form illumination is not obtained on all planes of reference nearer to the lamp than the original plane. Hence our problem becomes one of finding for any assumed value of K the minimum curve which will satisfy the condition of uniform illumination.
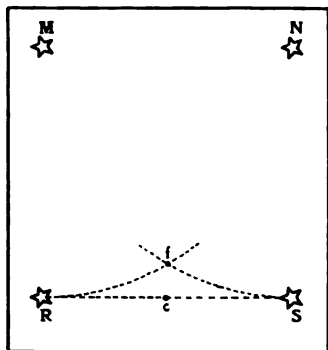
FIG. 6

Referring to Fig. 6, let us assume that the illumination from a given lamp reaches zero at a horizontal distance on the plane of reference equal to the side of the square. From M and N strike two arcs representing respectively the lines along which the intensity of illumination from M and N becomes zero. Now consider the point c. It receives equal illumination from lamps R and S. The point f, which by hypothesis has the same total illumination as point c, must receive equal illumination from lamps R and S. But f is at a greater horizontal distance than c. Hence, since f has equal illumination, the candle-power of R and S must be increasing as the horizontal distance increases. But this is contrary to the assumption that the intensity of illumination and hence the candle-power is decreasing and reaches zero at a distance equal to $R\,S$.

If we assume that the intensity of illumination reaches zero at a distance equal to Mc (or Nc), the above reasoning no longer applies.

Let us also assume a given separation of light centers and a mounting height corresponding to the assumed value for K. Now deduce the equations for the intensity of illumination at the points a, b, c and f, Fig. 7. The second member of these equations will

FIG. 7

consist of one, two or three terms, each term being a known constant times the unknown candle-power at a known angle. Remembering that these equations are all equal to each other, assume a given candle-power at each of the indicated angles, these candle-power values being so chosen as to lie on a smooth curve. Now deduce the illumination equations for other points h, i, j, and correct the assumed
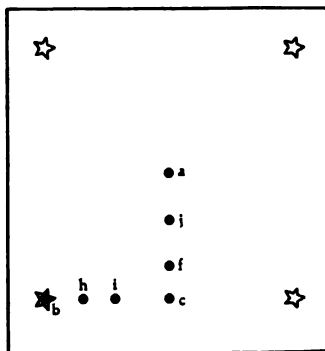
distribution curve so that its candle-power values satisfy all the equations. By continuing this method further, the exact distribution curve can be deduced to any desired closeness of approximation.

The correct distribution curves, derived by the method outlined above, are shown in Fig. 5.

To meet all conditions of the practical problem as we find it, we really need two distribution curves. For rooms having very high ceilings relative to the separation of light centers we need a distribution represented by the curve K=0.5 or the curve K=0.75. For rooms of more moderate ceiling height (relative to the separation of light centers) we need a distribution represented by the curve K=1.25 or the curve K=1.5.

One interesting feature of these curves deserves passing notice. The distributions representing a larger value of K will give uniform illumination when substituted for a distribution representing a smaller value of K. Thus the distribution for K=1.5 will give uniform illumination when actually installed for K=1. The amply sufficient objection to such substitution lies in the fact that the distribution representing the larger value of K, when substituted for the smaller, throws a great deal too much light on the walls. This, we have seen, is a serious evil, though it is minimized when the room is a very large one.
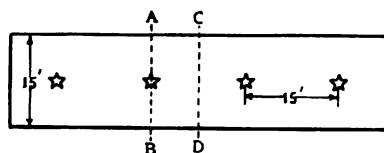
FIG. 8

GENERAL ILLUMINATION OF LONG NARROW ROOM
FROM LINE OF LIGHT CENTERS

It is important in determining the desired illumination results to keep closely in mind that this class of problems is comprised chiefly of the smaller stores. Here we want uniform illumination over the central portion of the store and extending well out toward the side walls. Near the side walls, the intensity of illumination may be allowed to drop a little, but it should in no case be less than half the central uniform value. The walls, too, should be illuminated rather brightly in order to show up the goods displayed. The arrangement of light centers for this class of service is shown in Fig. 8.

In this problem the distribution curve required to produce the desired illumination results depends upon

1—The width of room;

2—The separation of light centers, and

3—The height of light centers above the plane of reference.

For certain relations of width of room and separation of light centers, the problem of obtaining the desired illumination becomes impossible of solution. When, however, the separation of light centers equals the width of room, the distribution curves for single light centers (see Fig. 3) serve admirably to give the desired illumination described above. Each curve must be used, however, with the next lower value of *J*. For instance, in a long, narrow store, 15 feet wide, the separation of light centers should be 15 feet. If the distribution curve J=3 be used, the mounting height should be 15÷2.5 or six feet instead of 15÷3 or five feet. If the distribu-
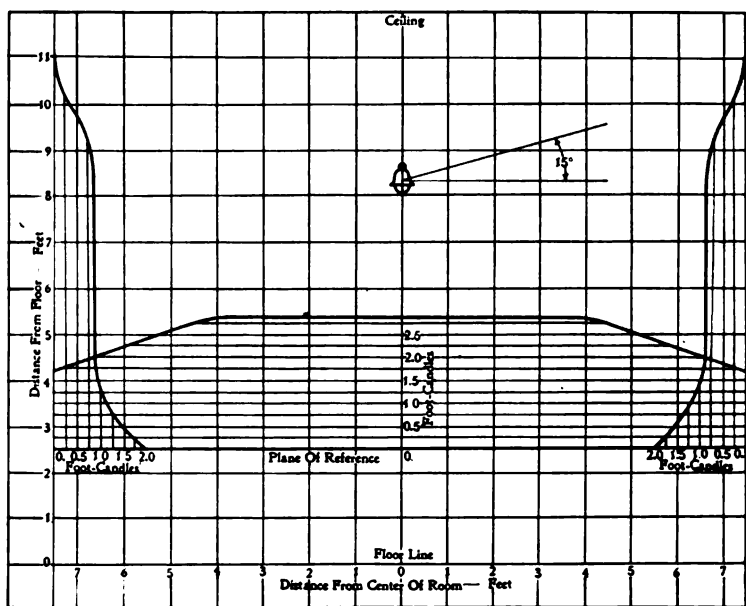
FIG. 9—TYPICAL FOOT-CANDLE CURVES
Showing illumination on section *AB*, Fig. 8.

tion curve J=2.5 be used, the mounting height should be 15÷2 or 7.5 feet instead of 15÷2.5 or six feet.

Typical illumination cross-sections of the store for the above case when J=3 are shown in Figs. 9 and 10. The locations of these cross-sections are given in Fig. 8.

SUMMARY

To obtain correct illumination results from a single light center or from a line of light centers, a distribution of the type shown in Fig. 3 is required. To obtain correct illumination results from multiple light centers arranged on the basis of the square, and to

próperly meet the wide variation of actual problems in the relation of height of room to separation of light centers, two properly chosen distributions of the type shown in Fig. 5 are required.

When the commercial interests furnish light units giving the three correct distributions, the problem of illumination design in what are frequently its most important factors—relative intensity of illumination, average intensity, and total number of light units required—will be reduced to the simplicity of a table which can be
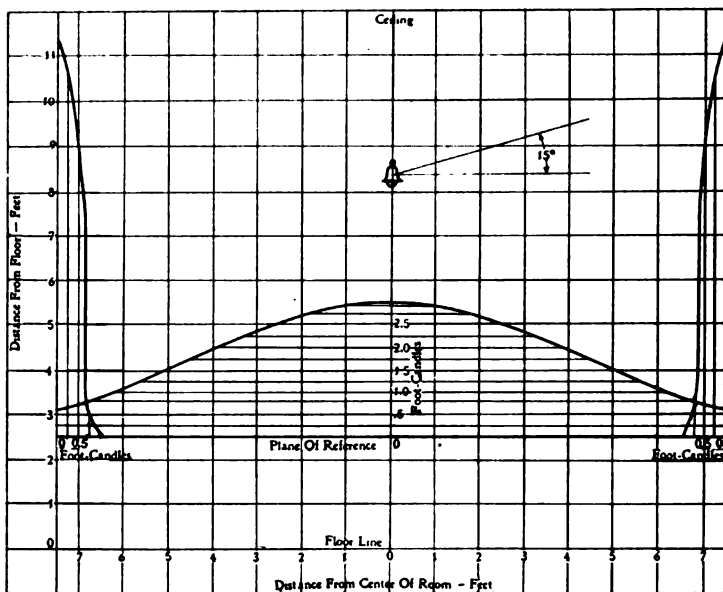
FIG. 10—TYPICAL FOOT-CANDLE CURVES
Showing illumination on section *CD*, Fig 8.

applied to concrete, practical problems by any intelligent man. When that day comes, we shall find correct illumination the rule in the home, the office and the store, and not. as at present, the rarely-met-with exception.

Nor is that happy day so far distant. There are to-day on the market three incandescent lamp units which roughly approximate to the curves J=2.5, K=0.75, and K=1.25. Steps are now under way to bring these curves into closer approximation with the ideal. All the incandescent lamp interests and the largest reflector interest are definitely committed to this line of progress. The one thing yet to be desired is· that the gas interests, the other reflector companies, and the fixture manufacturers fall into line.

THE GRAPHIC RECORDING METER AND ITS RELATION TO INDIVIDUAL MOTOR DRIVE IN INDUSTRIAL OPERATIONS

A. G. POPCKE

THE best basis for any method of securing economy in the operation of any large establishment is an exact knowledge of the existing conditions. This may be obtained by keeping continuous records, by personal observations or by means of graphic recording instruments, and carefully analyzing the results with the idea of making improvements. Graphic recording instruments have an advantage over personal observation, since they eliminate all personal element and errors, and also the extra expense incurred for additional help required for making observations. For this reason, the field for the use of graphic recording instruments has been continually developing.

The United States Weather Bureau was among the first to use such instruments in obtaining continuous records of atmospheric conditions. The introduction of recording steam pressure gauges has resulted in increased economy in the operation of steam plants, and as these gauges show the variation of steam pressure, the condition of the fires are indirectly recorded. By firing so as to keep a constant steam pressure better economy in the operation of engines results, as well as economy in the use of fuel. The time at which all variations occur is recorded and any disputes may at once be settled by referring to the record. Graphic recording ammeters and wattmeters have also been developed. These are of great value upon the switchboards of large central stations and also in the power houses of large industrial establishments. The total load of the plant, the load on the various units or the load on the feeders can be recorded at all hours of the day.

The economy of a central station is largely dependent upon its load curve. In an industrial plant the load curve is an indication of the rate of operating the entire plant. The total load curve of many industrial plants is slow in picking up in the morning and again starts to drop off about one hour before quitting time in the evening. When the load falls off, it indicates that all the machines are not working at their full capacities and there is considerable loss in productive output. Remedying this, therefore, means in-

crease in output with practically the same operating expenses. The best way to remedy any fault is to localize it. By placing graphic recording meters in the various feeder circuits, the most faulty may be discovered and steps taken to improve conditions. Wherever individual motor drive is employed, the operation of single machines may be studied.

It is the object of this article to show how a study of existing conditions can be made by automatically recording the operations of industrial plants by the use of graphic electric meters, and that by such a study valuable information may be obtained as to the best methods of economizing in operating expenses and improving equipment. In operating all machinery there is, almost without exception, an increase in power when an operation is performed. In some cases there is a definite relation between the operation performed and the amount of power consumed. Therefore, if a graphic record of these operations is taken, any particular operation may be distinguished by the amount of power which

FIG. I—GRAPHIC RECORDING METER
Large capacity type.

is consumed by the driving motor. This is especially true where an operation is repeated at short intervals. This will be explained by the use of an example.

Fig. I shows the type of meter employed to obtain graphic records. The instrument is unlike an indicating meter, in that instead of being provided with a needle passing over an indicating scale a pen moves horizontally, thus making a line on a properly graduated roll of paper. The paper is moved vertically or at right angles to the pen by clock work, so that a permanent record of the magnitude and time of all changes in power consumption is obtained.

Fig. 2 shows a record obtained from such a meter. The record should be read from right to left as indicated by the hour marks at the bottom. The height of the pen mark above the bottom line at any time indicates the power consumed at that time.

The record shown by Fig. 2 is a typical curve taken with a graphic recording ammeter connected in the circuit of a direct-current motor driving a roughing lathe. Fig. 3 shows the work which was performed on the lathe being observed. A shaft was turned from the stock size as indicated. Fig. 4 shows the lathe upon which the operation was performed.

In the following explanation *A, B, C*, etc., refer to corresponding points in Figs. 2 and 3. At nine o'clock a shaft was completed. During the interval of almost three minutes, marked *change,* the completed shaft was removed from
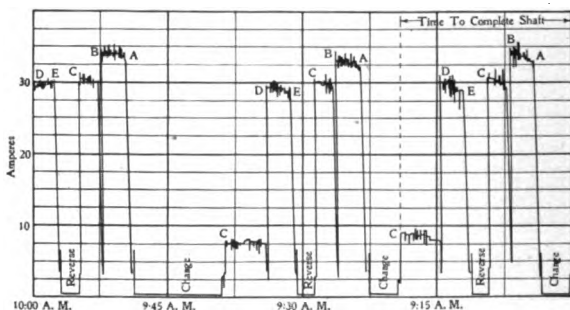
FIG. 2—GRAPHIC CURVE SHOWING A TYPICAL CYCLE ON A
ROUGHING LATHE

the lathe and replaced by a new piece of stock. The current during this period was zero since the machine was shut down. At *A* the lathe was started, the machine ran idle for a short period at about four amperes until the feed advanced the cutting tools sufficiently to make them cut into the stock; when this took place there was a sudden increase in power up to 32 amperes. This condition continued while the cut *AB* was taken. At *B* the power again decreased to four amperes, the machine running idle. The period *AB* represents the time required to take the cut *AB*. At *B* the diameter had to be increased from 2⅜ inches to 2½ inches, hence the feed was stopped and the cutting tools were adjusted to this new diameter. The time to do this is represented by the short interval at which the machine ran idle (four amperes). The power again increased

to 30 amperes when the cut *BC* was taken. The current is less than it was when *AB* was taken because the depth of cut was less, whereas the cutting speed and feed were not changed. At *C* the curve again indicates zero, the machine being shut down. During the interval marked *Reverse,* the half completed shaft was removed from the lathe, turned about and replaced with the turned-off end in the chuck. After this the cuts *ED* and *DC* were taken. As indicated by the small amount of power consumed, *CD* was a light cut. At 9:19, just before the interval marked *Change,* the shaft was completed. The cycle of operations is then repeated for every shaft turned out. By studying Fig. 2, the regularity of similar operations is evident. From a record of this type it is possible to analyze each operation into the items of time and power consumed, and the different methods of doing the same operation can be compared to find out which is the most economical. Also, by seeking an explanation
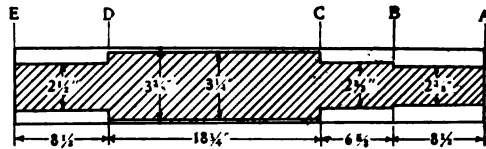
FIG. 3—DETAILS OF THE SHAFT TURNED WHILE
THE RECORD REPRODUCED IN FIG. 2 WAS OBTAINED

for all cases which do not come up to standard conditions, many improvements for facilitating operations will be suggested and in this way the output may be increased considerably without increasing the operating expenses.

The curve shown in Fig. 5 is part of a record obtained upon a graphic recording ammeter connected in the circuit of a motor driving a 72-inch boring mill. This record is given to illustrate improper use of an equipment. The motor driving the boring mill was of the adjustable speed type, controlled by a multi-speed controller, a combination well adapted to machine tool work since it is possible to use the most efficient cutting speed at any diameter. In this case the top of a circular disc was turned off, the cutting tool gradually feeding toward the center of the disc. The speed of the boring mill table was not increased as the diameter upon which the cut took place decreased. Hence, the cutting speed gradually decreased, the feed and the depth of cut remaining constant, decreas-

ing the rate of removing metal and consequently the power gradually decreased as shown in the record. If the speed of the table had been increased as the diameter decreased, keeping the rate of cutting constant, which was possible with the equipment, the time required to perform the operation would have been decreased, the saving in this case amounting to 40 percent of the total cutting time. In a busy shop a foreman has not the time to look into minor details, and even such important matters as the one just mentioned, obvious as they may seem after being discovered, are usually overlooked. By an occasional use of a graphic recording meter, such faults are detected and the operator may be properly instructed.

The above examples were cited to give an idea of the use of the graphic recording meter in industrial operations; it has been
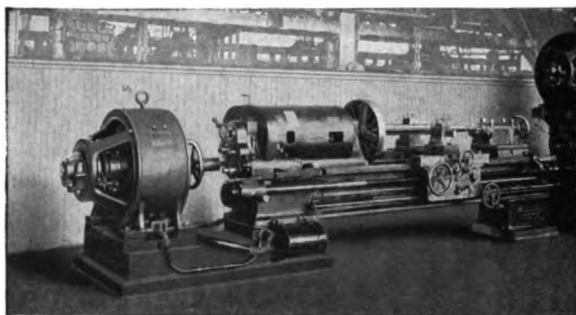
FIG. 4—MOTOR-DRIVEN 20-INCH RAPID REDUCTION LATHE
The meter was connected in the circuit of the 14 hp,
360—800 r.p.m. motor driving this lathe.

found that by its means complicated operations may be analyzed into elements of time and power, upon which depend the efficiency and economy of all industrial operations. The records of time and power consumed also show the exact working cycle for which the motor must furnish power. By an analysis of this cycle, it is possible to determine whether or not the motor is of the proper electrical and mechanical characteristics for the given service. Improper applications are often discovered by this means.

In making an investigation of the economy of operation by motor drive, too much stress is usually laid upon the cost of power. The first question which usually comes to the mind of the man who is considering the use of motors to replace an old equipment is, "How much power will I save?" If there is sufficient saving he will consider the new equipment. In the majority of industrial

establishments the cost of power, whether generated or bought, is one of the smallest items of operating expense. For example, in the large machine shops this item amounts to from one to two per-cent of the total hourly operating expense.

The overhead charges in large organizations are in most cases one or more times the wages of their workmen, and are usually not considered when figuring the saving secured by the reduction in the time necessary to perform various operations with a new equip-ment. These overhead charges, which continue whether an equip-ment is operating or not, include the following:

Interest and depreciation on the cost of the equipment.

Interest and depreciation on the cost of buildings, grounds and accessories.
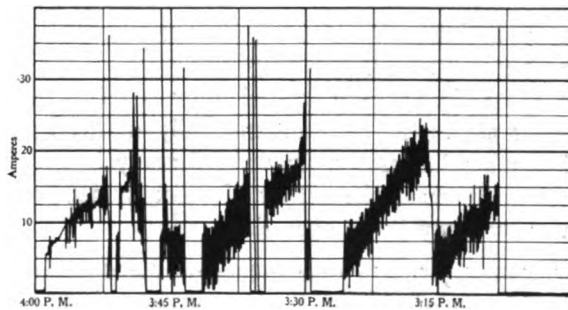
FIG. 5—GRAPHIC RECORD OBTAINED IN CONNECTION WITH A 72-INCH VERTICAL BORING MILL

The mill is driven by an 8.5 hp direct-current, ad-justable speed motor; 675—1 350 r.p.m.

Taxes and insurance on the equipment, buildings, grounds and accessories.

Loss due to defective material, design and workmanship.

General supervision and clerical work.

Power, heat, light, etc.

Hence it is important to keep an equipment constantly in service.

The three important items to be considered in determining the relative advantages of different kinds of equipment may be sum-marized as follows:

1—The *total* hourly operating cost.

2.—The percentage of the total time consumed in actual work.

3—The rate at which an equipment is operating while actually running.

For a given equipment the first item can be determined from the wages of its operators and the overhead operating cost. The second is a direct check upon the number of delays and requires personal observations and clerical records, thus increasing the overhead charges, unless there is some means of using an automatic recording device. Where individual motors are employed, this percentage may be determined directly from the records obtained by means of graphic recording meters, since these show all idle and no-load intervals. The third item is a direct check upon whether or not the rate of output is the maximum under the given conditions; determined in most cases by the mechanical strength of the parts operating, the accuracy of the workmanship required and other local conditions. With individual motor drive and the graphic meter, the magnitude of the records obtained, in many cases, indicates at a glance the rate of working.

Aside from the well-known advantages of individual motor drive, this simple method of automatically obtaining records, by which existing conditions are shown and many improvements suggested, tends to increase the output of an equipment and thus produce greater economy in its operation.

NOTE—This article has in a general way outlined the scope of the application of the graphic recording meter in determining the characteristics of industrial operations, both from the standpoint of economy in operating and the service which the driving motor must withstand. In later issues it is planned to publish articles describing the application of graphic meters and motors with reference to definite industries, such as machine shops, woodworking, paper mills, cement plants, etc.

PARALLEL OPERATION OF MACHINES WITH SERIES FIELDS

H. L. BEACH

THE widespread use of motors and generators having series fields and the large amount of preventable trouble arising from improper connections and adjustments of these fields, have convinced the writer that a short article dealing with the precautions to be observed in making connections to these machines will not be amiss. The preventable troubles that are experienced seldom, if ever, arise with installations involving only one machine, but occur when generators or motors are used in combinations. The various combinations may be grouped under two general heads, viz.: 1, Series and compound-wound generators; 2, series and compound-wound motors.

SERIES AND COMPOUND WOUND GENERATORS

When two or more series or compound-wound generators are operated in parallel, it is necessary to use what is called an equalizer between the various machines. The object of this connection is to maintain the desired equilibrium of loads between the generators in parallel under all conditions. On each machine one terminal of the series field is connected to the brushes of one polarity and the equalizer connection is made at this point on each machine so that all machines in parallel will have the same potential at the point where the brushes are connected to the series fields. In order that the potential may be exactly the same at all machines equalizer connections are of low resistance. In some cases the equalizer is in the form of a low resistance cable running directly from machine to machine, in others it is desirable to have an equalizer bus-bar on a switchboard, as indicated in Fig. 1.

If no equalizer were used it would be possible for the voltage of one machine to increase and thus take on more load. With increase of load the excitation due to the series field increases the voltage, which in turn increases the current, and this action may be continued until finally this machine takes all of the load and reverses the other machines, resulting in an action known as "bucking."

Generators are usually provided with adjustable series field shunts, the function of which is to vary the value of the full-load voltage or, in other words, the amount of over-compounding. The

usual practice when starting up two or more machines together is to
so adjust the shunts that the parallel machines will divide the load
in the ratio of their kilowatt capacities.   The method employed by
the writer, while well-known to many experienced engineers, does
not seem to be generally practiced.   Many instances have occurred
where it has been pronounced impossible to parallel certain genera-
tors which, after proper adjustments had been made, were found
to operate together satisfactorily.*

The adjustment of series wound machines is far more difficult
than that of compound machines, as with the latter the shunt field
is a more or less constant factor that can easily be adjusted slightly
to compensate for a poor series adjustment.   The reason for the
difficulty in adjusting series machines will appear from a study of
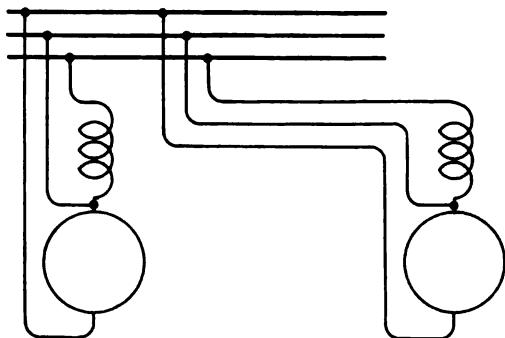
FIG. I—TWO SERIES MACHINES IN PARALLEL ON
COMMON BUS-BARS
Showing equalizer bus-bar and connections.

Fig. 1.   Assume that the two machines in question are located so
that the leads from one machine to the switchboard are twice as
long as the corresponding leads of the other machine.   Between
the equalizer and the positive bus-bar the total full-load current will
divide unequally in the two fields on account of inequality of lead
resistance, which though small will make a great difference where
the total resitance is so small. Being series generators, with no shunt
field to steady the action, the voltages of the two armatures will differ
considerably and the net result will probably be that one armature
will assume several times the load of the other.   It will therefore
be necessary to add resistance to the leads of the machine nearest

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*A case such as this was illustrated in an article in the JOURNAL for
September, 1909, p. 563.

the switchboard so as to make its field resistance exactly equal to that of the other machine.

To properly divide their load, it is necessary that the series generators be at the same temperature when adjustments are made. If the adjustments are correct when one is warm and the other cold, the cold machine will lose its load gradually as it warms up. If a cold machine is connected in parallel with a warm machine with which it has been properly adjusted to run in parallel, it will at first take the larger share of the load. As it warms up, however, and the field temperatures and resistances bcome equal, the difference in load will gradually decrease until each machine takes its adjusted share.

In the case of two compound machines of unequal capacities and different compounding characteristics which are to be paralleled; the worst combination would be that of a large generator with "even" compounding and a small generator with a large compounding, the operating conditions demanding all the over-compounding possible. By adding resistance in series with the series field of the small generator, an adjustment can be obtained which will allow only such a part of its full-load armature current to flow through its field as will give a compounding effect equal to that obtained when the armature current of the large machine, plus the remaining armature current of the small machine, flows through the series field of the large machine.

Example: A 2 000 ampere even-compounded generator is to be paralleled with a 400 ampere generator which over-compounds 20 volts at full-load. The resistance of the field and leads of the 2 000 ampere generator is 0.02 ohm; that of the 400 ampere generator is 0.1. The drop in the series field is therefore equal for equal percentage loads and the current in the field would, therefore, divide in the ratio of one to five. Tests show that 200 amperes in the field of the smaller machine at full-load will just give *even* compounding, and that 2 800 amperes in the field of the large generator with 2 000 amperes in the armature will give 20 volts over-compounding. To get the two machines to compound equally, the remaining 200 amperes of the small generator must be divided between the two fields in the ratio of 200 to 800, or one to four. At full-load, then, the large generator should have 2 000 + 160 amperes in its field; and the small generator should have 200 + 40 amperes in its field; hence the field resistances should be in the inverse ratio of 240 to 2 160 or $R : r = 240 : 2 160$. R actually equals 0.02 ohm,

so that *r* should equal 2 160 $\times$ 0.02 $\div$ 240 or 0.18 ohm. But *r* =
0.1 ohm by original assumption, so that it will be necessary to add
0.08 ohm resistance to the field of the small generator. The two
generators will then run satisfactorily and, with rated full-load cur-
rent in each armature, the resultant over-compounding will be
800:20 = 160:x (or 200:20 = 40:x) or 4 volts.

In the case just given, had it been desirable to obtain even com-
pounded and then parallel the two. If the field resistance alone was
0.06 ohm (leads=0.04), to reduce the field current to 200 amperes
at full-load (400 amperes) it would have been necessary to place a
shunt of 0.06 ohm across the field terminals. The equivalent field
resistance would then have been 0.03 ohm instead of 0.06 ohm as
originally assumed, or a total resistance of 0.07 ohm. The gen-
erators now compound exactly alike, and yet if they were
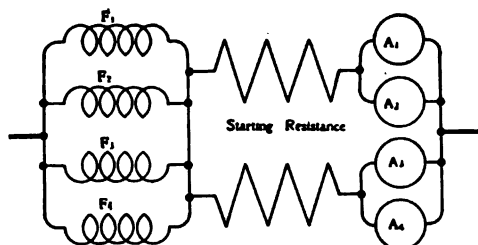
FIG. 2—FOUR SERIES MOTORS IN PARALLAL
This method of connection requires careful
adjustment of the resistances of the field circuit.

placed in parallel without first adding enough resistance to the
small generator field to bring it to its original value, the total com-
bined full-load current of 2 400 amperes would divide in the inverse
ration of 0.02 to 0.07 or 533 amperes would then go through the
field, an impracticable condition. The addition of 0.03 ohm to the
field leads of the small generator would equalize the load perfectly
throughout the whole range.

SERIES AND COMPOUND-WOUND MOTORS

With motors no equalizers are necessary as there is no tendency
for the motors to buck each other as with generators. In fact, ex-
cept where motors are used as generators for electric braking, as
in street railway work, an equalizer connection is generally consider-
ed very bad practice. This point should be kept carefully in mind

as it frequently occurs that a second motor is added to a hoist to increase the power and, in this case, great care should be exercised that the fields and armatures are not individually paralleled.

A recent installation of this kind was made where four motors of about the size of ordinary street car motors were geared permanently to the load and the control apparatus simplified by connecting the four fields in parallel. The connections were eessentially as shown in Fig. 2. Thus far the apparatus has been working very well, but careful field adjustments are necessary which, in practice, are not always practicable. Should a field coil become partially open-circuited on any motor, its armature, having a weakened field, would at once take all the load and unless the trouble was discovered at once, the armature would burn out. Suppose that a field lead becomes broken, e.g., F_1, Fig. 2; armature A_1 would take all the cur-
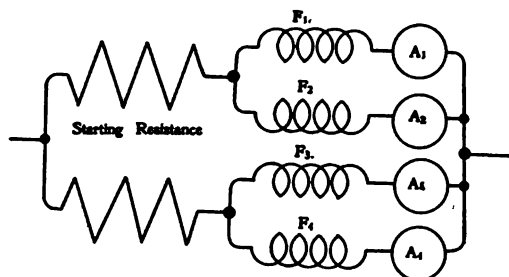
FIG. 3—FOUR SERIES MOTORS IN PARALLEL
This method is found to be more certain in giving proper division of load.

rent in its part of the circuit, since it would generate no counter e.m.f. The other pair of motors, *3* and *4*, would run the machine, and armature A_2, having a strong field, would generate through armature A_1, acting as a short-circuit on No. 2, thus giving rise to an excessive current. If there were no circuit-breakers or fuses in this circuit, armature A_1 would, of course, be burned out.

In this case, if the fields were separated from each other and reversed separately, the opening of a field could do no harm, since the corresponding armature would be open-circuited at the same time. This scheme of connections is shown in Fig. 3 and is considered a safe and more correct method for the parallel operation of four series motors. In the early stages of street railway development, this fact was not taken into account and the resultant armature burnouts kept a large force of repairmen constantly at work. When

the cause of the trouble was finally located, instances were found where, on a two-motor car, one motor was generating full-load current and the other was driving the car and the added load of the generating motor. Changing the controllers so as to keep all fields and armatures separate reduced the repair force to about ten percent of its former size.

In paralleling any two compound-wound motors, it is only necessary to have the speed regulation exactly alike to make them divide their load properly. Example: A pump operated by a 75 hp motor is to be changed to a place where the work will overload the motor and a 25 hp motor is added to help out. The 75 hp motor runs at 550 r.p.m. at no load and 500 r.p.m. at full-load, with 300 amperes in its series field and armature circuit. The 25 hp motor runs at 1 100 r.p.m. at no load and at 1 050 r.p.m. at full-load with 100 amperes in its armature and field circuit. The percent change of speed with the 25 hp motor is therefore only one-half that of the 75 hp motor, so that the 25 hp motor will take full-load current when the 75 hp motor has only half load. If the series field of the 75 hp motor be shunted so that at full-load its speed is 525 r.p.m., it is apparent that the two machines may be geared together and divide their load in proportion to their ratings.

With single-phase commutator motors another factor enters into the problem, which tends to reduce the necessity of resistance equalization. This is the inductance of the fields which is of such a constant and reliable value that the field resistance can be practically neglected. Thus the motors on the cars and locomotives of the New Haven Railroad have their fields connected in parallel pairs when running on alternating current.

In conclusion, it should be assumed in general that any connection of series motors which allows of different values of current in armature and field of individual motors is unsafe. Where series motors are used in pairs, the work is usually of a severe nature, such that open and short-circuited fields are far from being unheard of and where the very character of the work precludes the fine and delicate resistance adjustments that are absolutely necessary with any other scheme of connection. A few more fingers on a controller or a few more switches on an automatic switching device are cheap insurance and cost far less in first cost and in repairs and attention than the loss of an armature or the delay of an important operation dependent on the successful performance of the motor equipment.

MULTIPLE UNIT CARS FOR THE NEW HAVEN RAILROAD

L. M. ASPINWALL

A LITTLE over two years ago the New York, New Haven and Hartford Railroad Company completed the electrification of their lines between Stamford and Woodlawn and commenced to handle their traffic over this section by means of single-phase electric locomotives. These locomotives were arranged to operate not only on single-phase alternating-current, but also on 600-volt direct-current in order to enable them to run on the tracks of the New York Central Railroad into New York City. The plans of the railroad contemplated the electrification of their lines not only on the Stamford section, but eventually as far as New Haven and possibly Boston. For this reason the locomotives had
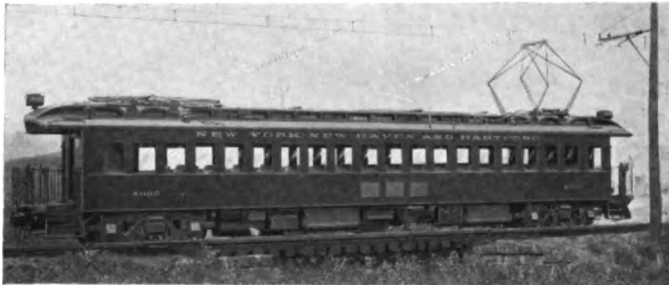
NEW HAVEN MOTOR CAR

to be designed for safe and effective operation at high speed on through line service, and in addition to meet the conditions already mentioned. The production of a locomotive to fulfill all these requirements necessitated the adoption of a design different from what would have been used had local service been the only consideration. After the electrified section of the line had been in operation for about nine months and the success of the single-phase installation demonstrated, the management of the road decided to purchase some multiple unit cars which would be primarily designed to handle the suburban service. It was decided to order four motor cars and six trail cars as the first equipment. The first of these cars has been completed, equipped and shipped and the

balance will be ready in the course of a few weeks.

The cars and trucks were built by the Standard Steel Car Company and are of the double truck type, 70 feet long and built of steel throughout, no wood being allowed to enter into the construction. The interiors are handsomely finished to represent mahogany and the work is so perfectly done that a most careful inspection is necessary to convince one that wood is not employed. Cross seats are supplied to seat 76 people. These seats are upholstered with smooth green pantasote and the ceiling and interior trimmings are also of light green, which gives a very pleasing effect. The floor is of cement throughout the whole car. A motorman's compartment is provided in the right hand corner of each of the cars. These compartments are provided with folding doors and seats so arranged that when not in use by the motorman, seating room is provided for two passengers, and at the same time the operating mechanism is entirely screened by the doors.

INTERIOR VIEW OF NEW HAVEN MULTIPLE UNIT CAR

Each motor car is designed to pull two trail cars operating upon the required schedule between New York and Stamford, and for a maximum speed of 50 miles per hour. The cars are equipped to operate on both 11 000 volts single-phase and on 600 volts direct-current. The motor equipment consists of four 150 horse-power, Westinghouse single-phase geared motors, two of which are mounted on each truck.

The motors are geared to the axles by single reduction gears, but instead of the gears being mounted directly on the axles they

are mounted on quills which surround the axles, leaving a space of 9/16 inch between quill and axle. The general construction of these quills and the method of connection between them and the wheels is practically the same as that employed on the New Haven locomotives. The ends of the quills terminate in discs which are provided with four projecting drive pins which fit into corresponding pockets provided in the wheels. A helical spring wound with the turns progressively eccentric surrounds each of the driving pins and presses upon the interior walls of the wheel pockets. These springs carry the weight of the quill, gear, and approximately half of the motor, and at the same time transmit all of the driving action to the car wheels. The motor nose is spring suspended from the truck transom. With this arrangement of mounting the weight of the motor is entirely spring supported and the torque is transmitted smoothly to the wheels, both of which features add considerably to the good riding qualities of the car. The motors are of the six pole series type and are provided with a main and compensating field winding, the latter being permanently connected in series with the armature. An opening is provided in the upper half of the field frame so that forced ventilation may be employed. The continuous capacity of

MOTORMAN'S CAB

Showing combination multiple unit master switch, air brake control valve, air pressure gauge, blower motor control switch, etc. This apparatus is duplicated on each end of the motor cars and trailers.

each motor with forced ventilation is 450 amperes. The gear ratio employed is 23:76 with 42-inch wheels. Air for the forced ventilation of the motors and transformer is supplied by means of a motor-driven centrifugal blower located under the car near the center. The air is lead from the blower to the motors by means of a conduit formed in the framing of the car by the two center sills and a cover plate.

The electro-pneumatic system of control is used and the connections are such that the motors are connected two in series and two in multiple on alternating-current; and all four in series, or two in multiple and two in series on direct-current. A master controller is placed in each motorman's compartment on both the motor and
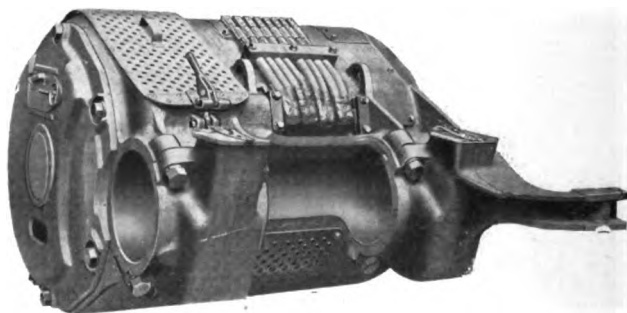
150 HORSEPOWER SINGLE-PHASE MOTOR USED ON NEW
HAVEN MOTOR CARS

trail cars and the operation of the train can, therefore, be directed from either end of any car in a train. Automatic acceleration is provided for in the control system and the rate of acceleration is controlled by series limit switches located in the motor circuits. A push button is provided on each master controller so that, if desired, the automatic feature can be cut out should occasion arise where "hand notching" is required.

A single air blast transformer, suspended under the center of the car, is used to step down the 11 000 volt line current to the voltage required for the operation of the motors.

Two pneumatically operated pantagraph trolleys are provided, one being located at each end of the car. The design of a trolley, which could be used in the small tunnel clearances available, without handicapping the design of the car, required most careful attention, but the arrangement used has proven very satisfactory. Connection is made from the two trolleys to the transformer through an

oil switch which is operated pneumatically from the motorman's compartment, and which is also provided with an automatic overload trip. On going from the alternating to the direct-current section of track, the change from the trolley to the third rail is made by means of an air-operated automatic change-over switch, which is controlled by relays. The change from alternating to direct-current is made while the car is operating at full speed and is made so smoothly that only a momentary wink of the lights is noticeable as the change is made.

Both the motor and trail cars are equipped with quick acting automatic air brakes of the latest type. The compressed air for the brakes and the operation of the control apparatus is supplied by a duplex motor-driven compressor suspended beneath the car. The compressor has a delivery capacity of 35 cubic feet of free air per
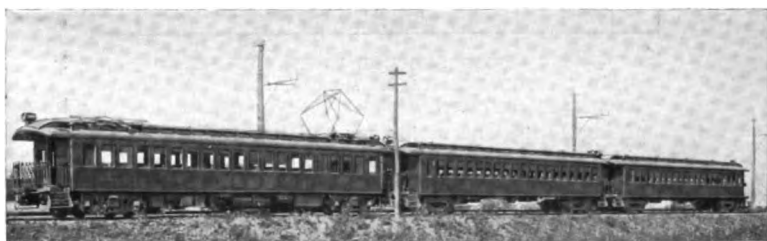
THREE-CAR MULTIPLE UNIT TRAIN

minute, and it is supplied with an air cooled head so that, if required, it may be operated continuously without overheating.

The motor cars completely equipped weigh 173 400 lbs., and the trailer cars 99 000 lbs. The operation of the cars in general is very smooth and their riding qualities are excellent. Careful operating tests of these equipments are being made on the test tracks of the Electric Company at East Pittsburg and the results so far obtained are very gratifying.

Curves shown in Figs. 1 and 2 give the results of one of these tests made with a train consisting of one motor car and two trailers operating upon a run 1.55 miles long. Fig. 1 shows the run east and Fig. 2 the run west over the same stretch of track. It may be seen from the speed and time curves that, in spite of the heavy load of two 50-ton trail cars, the average acceleration up to 25 miles per hour is considerably over 0.5 miles per hour per second. These curves are plotted from simultaneous readings, taken on the car, of speed, volts, kilowatts and amperes. The first part of the motor ampere

curves show very distinctly the automatic notching action of the
control. The speed was taken by means of a generator connected
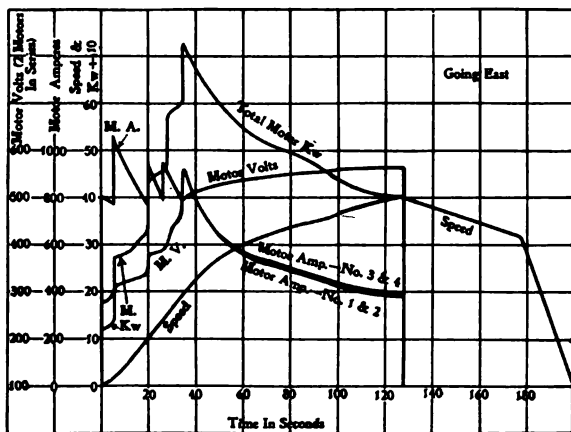
FIG. I—TEST CURVES SHOWING POWER CONSUMPTION AND
SPEED CHARACTERISTICS OF MOTORS, AND OPERATION OF
AUTOMATIC CONTROL
Going East—One motor car and two trailers.

to one of the main driving wheels and used in connection with a
voltmeter calibrated in miles per hour. The two sets of curves are
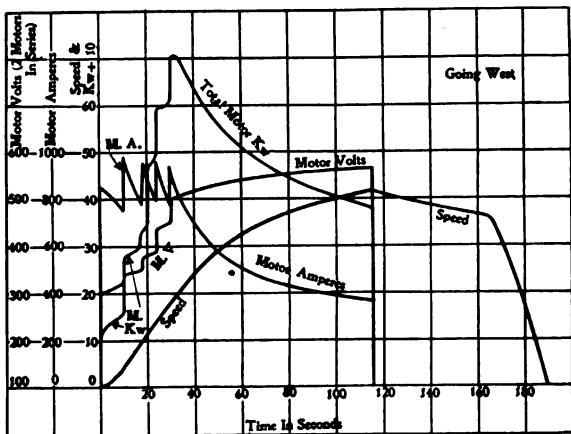
FIG. 2—TEST CURVES SHOWING POWER CONSUMPTION AND
SPEED CHARACTERISTICS OF MOTORS, AND OPERATION OF
AUTOMATIC CONTROL
Going West—One motor car and two trailers.

shown in order to give a fair representation of the operation of the
cars without regard to grades, etc., of the test track.

THE CHOICE OF A CONDENSER (Concl.)

FRANCIS HODGKINSON

THE CHOICE OF A JET CONDENSER

Of all the types of condensers described, the choice will be along one of three lines:

1—Either the plain jet or the centrifugal jet.

2—The barometric jet.

3—The ejector condenser.

Types *2* and *3* may in some respects be considered together, inasmuch as they are of the same variety. Cost is in favor of the ejector type, since no air pump is necessary. Experience, however, leads us to believe that with these more water must be handled, so that if water is scarce in the proposed location the ejector condenser would be at a disadvantage. Furthermore, the greater amount of water also entails greater expenditure of power in pumping, which may or may not be important. The lesser cost of the ejector condenser may readily be offset by the fact that any small air leak will entail a greater loss of vacuum. However, there are various installations where ejector condensers are doing good work.

The choice now lies between the barometric, either the ejector type or straight barometric, and the jet condenser, either plain jet, centrifugal jet or Leblanc condenser, when the following become the determining points:

1—The power required to operate the condenser, if important.

2—The amount of pumping required to be done, whether pumping in or pumping out of the condenser.

3—The loss of vacuum due to the long exhaust pipe.

4—Entrainer losses.

Regarding the pumping required, where a barometric condenser may be advantageously installed, the amount of pumping required is least. While the water enters the plain jet condenser by gravity, both the condensed steam and the cooling water must generally be pumped out against a 34-foot head. With a barometric condenser, assuming the hot well water is at the same elevation as the cold well, the vacuum in the condenser will elevate the water from the cold well by atmospheric pressure by an amount corresponding to the vacuum in the condenser. Say a 28-inch vacuum

is being maintained, this water would be elevated 32 feet and if the point of admission of cooling water is 40 feet from the level of the cold well, then the head of water actually to be pumped is approximately the difference between these two elevations, viz., eight feet. Of course, taking the cold well and the hot well at the same level and the injection to the condenser located 40 feet from this level, is very favorable to the barometric condenser, leaving out any consideration of the exhaust pipe losses; but in locations where there are considerable tide variations or floods, the condenser must be elevated that much more to allow for this, that is to say, the distance from the maximum high water to the base of the condenser cone must be about 34 feet. In using the previous figure of 40 feet to the injection, a condenser was assumed whose dimensions would approximate six feet total height of condensing cone. If an allowance of 20 feet, for example, had to be made for high water above normal level, then the distance from the normal hot well level to the base of the cone would have to be 34 feet plus 20 feet or 54 feet, and it would only be during flood times that the water would not have to be elevated more than the eight feet, as in the first instance. At normal water level the water would have to be handled 28 feet and it would only be at flood times that the advantage of the barometric condenser would be realized. Then, irrespective of any exhaust pipe losses, the barometric condenser would have no advantage over the jet condenser in the way of having to handle the water at a lesser head. It might be broadly said, still ignoring exhaust pipe losses, that where tide variations of 15 or 20 feet have to be allowed for there is no advantage in the barometric condenser.

With a jet condenser the cooling water and condensed steam must generally be pumped out against a 34-foot head. This, however, is not always the case as, if the condenser pump be elevated an amount above the hot well, some benefit may be derived from the head. To be able to realize the full benefit from this head, the discharge pipe must evidently be proportioned more or less to the exact amount of the water so as to maintain the pipe always full; that is, free from voids. If the pipe is too big the benefit of the siphon cannot entirely be taken advantage of, as there will always be some air being discharged with the water. If the pipe is much too big, a condition of affairs like Fig. 23 will exist, when obviously but little advantage whatever is to be obtained from the head, particularly when any air is being discharged with the

water. However, the water flowing down the pipe will always produce some entrainment.

It sometimes happens in installations where there are great variations of tide or where the engine room must be sufficiently elevated above the water level to be out of danger of floods that the advantages of a barometric condenser cannot be taken advantage of. In this case the general procedure is to employ a centrifugal jet condenser with two centrifugal pumps—one to force the water into the condenser and the other to eject the water from the condenser. At times of low water the inlet pump would be doing the most work. At times of high water most of the work
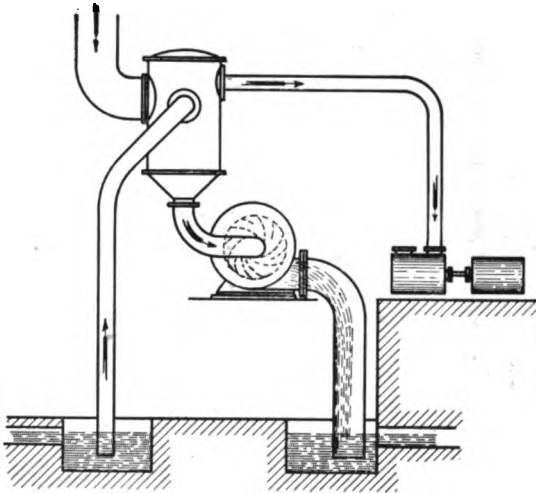
FIG. 23

will be done by the discharge. This type of condenser has been installed at the Brunots Island plant of the Pittsburgh Railways Company.

A barometric condenser would more frequently be indicated were it not for one indeterminate feature, viz., the fall of pressure in the long exhaust pipe. The loss due to the entrainer is pretty well known and has been pointed out before. The drop of pressure in the exhaust pipe, however, is not generally known and the writer has no figures to submit that are of any value. Inasmuch as a centrifugal jet condenser can generally be arranged with substantially no exhaust piping at all, preference should be given to the jet condenser wherever the advantage of the barometric are not very marked. It is at least fair to assume that from one-fourth to

one-half inch loss of vacuum is bound to exist in a barometric condenser unless the exhaust pipes are inordinately large.

It sometimes happens in a power plant that the engine room floor is well above the normal water level, but still not high enough so that the cone of the barometric condenser will be below the turbine, in which case the condenser may be placed slightly to one side of the turbine with the barometric cone some few feet above the floor. As the exhaust pipe still remains short, the losses may be small. Such an arrangement is shown in Fig. 24.

A number of plants have been constructed lately which are
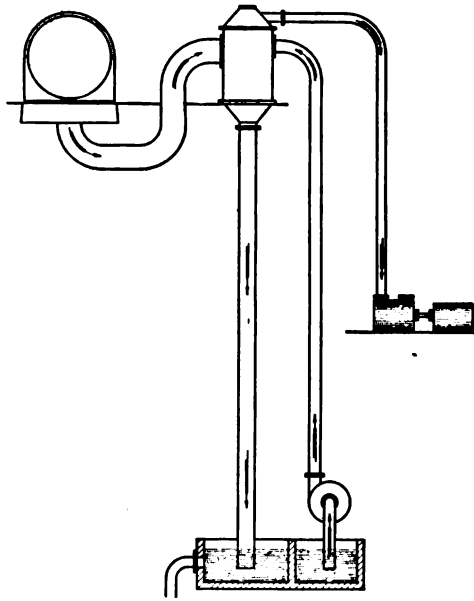
FIG. 24

likely to become a standard type. This is made possible by the fact that some types of turbines will operate entirely satisfactorily on structural steel work. This is the case in power houses of the type of the Ft. Wayne & Wabash Valley Traction Company, the Youngstown & Ohio River Railroad Company and the Cincinnati Traction Company, where the boilers are placed on the ground floor with the engine room above. This elevates the turbines sufficiently so that barometric condensers may be placed directly underneath the turbines, involving no exhaust pipe at all, the tails of the barometric condensers passing down between the boilers into

the water flumes below.   In these cases, if it is not necessary to re-
turn condensed steam to the boilers, there can be no argument
against the barometric condenser, either of the ejector or the straight
barometric type.

There is one advantage of the barometric condenser over any
other type where the cooling water is acid inasmuch as chemical
corrosion is much more active the higher the temperature.   The
pumps on the barometric condenser will not suffer so much as on a
jet condenser inasmuch as the water they handle is colder.   Then
the barometric condenser itself, the condensing cone and tail pipe
may be lined with lead or lead combined with five percent of anti-
mony (the latter rendering it a little harder) when the condenser
will be impervious to acids.   The original condenser installation
in the plant of the Westinghouse Air Brake Company's works at
Wilmerding was carried out by The Westinghouse Machine Co.
and consisted of simple jet condensers with dry air pumps, the
latter designed on the lines of Fig. 23, with a plain plunger water
pump below, the condenser being motor driven.   The condensers
gave an admirable performance when new, but the acid water
rapidly deteriorated both iron and brass parts.   For the protection
of one of these condensers lining it with lead was tried, which by
no means helped matters and, indeed, a little reflection readily
shows that no lead lining could be expected to remain intact in a
pump inasmuch as at every stroke of the pump the pressure within
it must change from the vacuum pressure to that of something
above atmosphere so that any air entrapped back of the lead
lining expands and contracts at every stroke of the pump, mak-
ing the lead lining like a bellows, which very soon broke it.   The
acid water getting in behind is similarly washed back and forth
thus making the corrosion more violent with the lead lining than
without it.   This condenser installation was discarded and replaced
by a barometric type in which the tail pipe was made of lead.   The
barometric head was made of cast iron lined with antimonial lead
castings.   All the baffles and spraying devices were similarly made
of antimonial lead.   The centrifugal pumps were made of cast iron
entirely, the shaft was encased with babbitt and the bearings were
entirely isolated from the pump housing so that it might be an in-
expensive matter to replace the runners or the pump housing, when,
as was to be expected, these parts had to be replaced.   To further
facilitate the   replacing of these, two injection pumps were fur-
nished for the one condenser and arranged so that   for normal

opération the two pumps would be in service, maintaining a 28-inch vacuum. When the necessity arose one pump could be taken out of service and the condenser operated on the remaining one, maintaining a 26-inch vacuum. The changing of the pump runners subsequently came to be looked on as a serious matter and some special bronze runners were substituted. However, the condenser generally is giving the best of satisfaction and corrosion is no longer a trouble.

Fig. 25 is of interest as showing the variation in temperatures
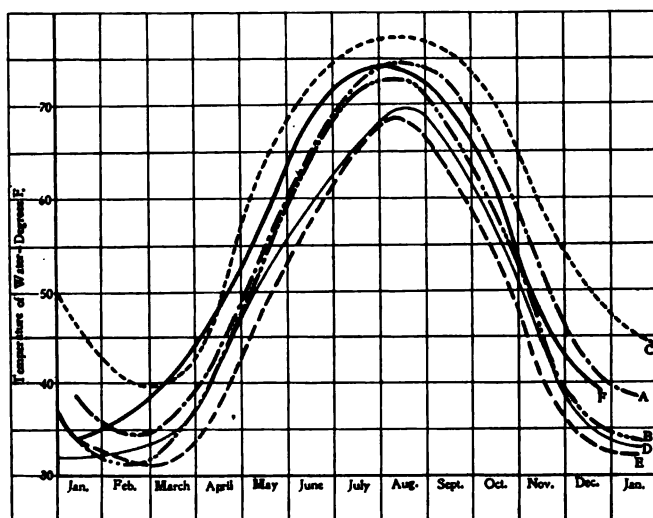
FIG. 25—CURVES SHOWING TEMPERATURE VARIATION OF CONDENSING
WATER AT VARIOUS LOCALITIES.

A—Average temperature at 24th Street, East River, New York.
B—Average temperature at 57th Street, North River, New
   York.
C—Maximum temperature at 24th Street, East River, for any
   one month for three years.
D—Minimum temperature at 24th Street, East River, for any
   one month for three years.
E—Lake Michigan at 2-Mile Crib, Chicago, 1905. Surface and
   bottom show no variation.
F—Mean temperature for six years at Horse-Shoe Bay, Sandy
   Hook, N. J.

of the waters which are available for condensing purposes in and around New York harbor and Lake Michigan throughout the year.

In this connection, some proper judgment should be used in determining the vacuum for which a condenser should be designed,

having been given the temperature throughout the year of the available cooling water. In a jet condenser it may be said that its cost is roughly proportional to the amount of water handled. Taking a hypothetical location where the water averages 80 degrees for say three months in the year, and 50 degrees for nine months; a condenser to produce a 28-inch vacuum during the 80 degree period, and capable of working with a five degree temperature difference, would require 57 pounds of water per pound of steam, while during the cold water period, it would require but 20 pounds of water per pound of steam. Or, it would be able to produce a 29.2-inch vacuum during the cold period, supposing the condenser were still capable of operating with a five degree temperature difference and supplied with the 57 volumes of cooling water. In a case such as this, it would probably be better to figure on a condenser taking perhaps 26 volumes of water; then for the three months period, a vacuum of 26.6 inches would be maintained, and a 28.6-inch vacuum during the nine months period. In this case a condenser could be used of about half the capacity required if a 28-inch vacuum were to be maintained during the 80-degree period. There is also another point which is, that condensers are capable of operating with a much smaller temperature difference with a low vacuum than with a high vacuum. This is due, in part, to the greater volume of the given quantity of air, and to the difficulty in cooling the air materially below the temperature of evaporation of the water in the condenser, or more properly, adjacent to the suction of the air pump.

CONCLUSION

In reviewing what has been written the writer feels that no broad rules have been laid down governing the choice of a condenser. Probably each job must be taken individually on its merits. He has, however, in the foregoing called attention to various points of design, both good and bad, and the features that must be reckoned with in making a choice. If asked to express in a few words any governing rule he would say: "Do not use a surface condenser unless condensed steam must be returned to the boilers and it is sure to be a paying investment, remembering that in the surface condenser the cooling medium does not intimately mix with the steam. Choose a plain jet or centrifugal condenser rather than a barometric unless the advantages in the particular layout in favor of the barometric are very certain."

THE ACTION OF DIRECT-CURRENT METERS ON RECTIFIED CIRCUITS

PAUL MacGAHAN

I N view of the extensive use of rectified currents for illumination, for battery charging and other purposes, the question of proper meters to use in measuring these currents is one of considerable importance. The load current taken from a rectifier has a form shown by the oscillograph record, Fig. 1. It will be apparent that this record closely resembles a direct current with an alternating current superimposed upon it. The undulating portion is generally spoken of as the "ripple."

There are in general two classes of indicating meters available for measuring uni-directional currents, viz:—

1—Those meters in which the torque is proportional to the first power of the current, i.e., permanent magnet, moving coil meters, designated as operating on the D'Arsonval principle. Examples: West-
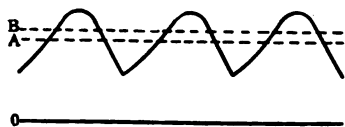
FIG. 1—CHARACTERISTIC WAVE FORM OF CURRENT IN RECTIFIED CIRCUIT

$O =$ zero value, $A =$ average value, and $B =$ square root of mean square value.

inghouse types D, E, H and L, Weston D. C., etc. In this class also are the instruments having a moving coil operating in a field produced by an electro-magnet excited by a separate, constant potential circuit. Example: General Electric Company's "astatic" meters. Instruments under this classification will not indicate on alternating currents.

2—Those meters in which the torque is proportional to the square of the current, such as the hot wire meters, the dynamometer meters which have a coil moving in the field of the stationary coil in the same circuit, and the magnetic vane meters which have a stationary coil and a movable iron needle or vane which actuates the pointer. The latter, i. e., the "moving iron" meters, may more properly be stated to be intermediate between the two above classifications for, if the iron is worked at a low induction, they have a torque proportional to the square of the current, but if, as in the Kelvin sector ammeter, and Westinghouse type K meters, the iron is supersaturated, they more nearly approximate in their

torque to the first power of the current. Among the dynamometer type meters may be mentioned the Westinghouse precision meters, type Q portable meters, the Weston alternating and direct-current voltmeters and many others; among the moving vane type, the General Electric Company's inclined coil types, the new direct-current and alternating-current Weston types, etc.[1] The Westinghouse type K belongs to that intermediate class, in which the moving iron is super-saturated, in order to obviate any residual errors. Instruments under this second classification will indicate on alternating as well as direct-currents.

The first of the above two general classes of meters indicate according to the electrolytic definition of an ampere, i. e., the current which, under fixed conditions, will deposit a certain amount of a given metal per unit time. The second class indicate according to the dynamic definition of an ampere as being the current which, passing through a certain resistance, will produce a given amount of heat. In the first case, the rate of depositing the silver is pro-
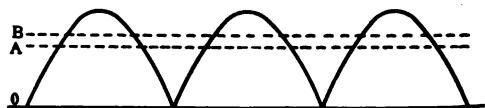
FIG. 2—RECTIFIED SINE WAVE
$O =$ zero value, $A =$ average value, and
$B =$ square root of mean square value.

portional directly to the current, and in the second case, the heat produced is proportional to the square of the current.

These considerations will lead to a clear understanding of the action of various meters on rectified currents, and the choice of meters having the proper characteristics. Referring to Fig. 1, a meter of the first class will measure the average current or OA, which is equal to the value of a constant current having the same chemical effect, as in charging storage batteries. A meter of the second class will measure the "square root of the mean square" value of the current, OB, which is equal to the value of a constant current having the same heating effect as the rectified current.

In certain apparatus such as storage batteries, the ordinary measurement desired is the electrolytic value or first power of the current, thus requiring instruments of the permanent magnet type on rectified circuits. If it is desired to measure power in rectified circuits by the ammeter-voltmeter method it should be remembered

that the power in any circuit is equal to the summation of the prod-
ucts of the instantaneous values of current, multiplied by corre-
sponding instantaneous values of voltage. The power is not neces-
sarily the product of the square root of mean square value of the
current multiplied by the square root of mean square value of the
voltage, as this is true only in the case of pure sine waves, in phase.
Hence, if it were attempted, by means of voltmeters and ammeters,
to measure the direct-current power in a rectified circuit used for
charging batteries, or for other devices having a practically con-
stant e.m.f., i. e., practically independent of the current, the meters
used being of the "second power" or "current-squared" type, con-
siderable error would be introduced, and much closer results would
be obtained by the permanent magnet type. The most accurate re-
sults would of course be obtained by means of wattmeters, which
automatically measure the product of the instantaneous values of
current and voltage.

However, in measuring the rectified circuit power in apparatus
in which the power is proportional to the square of the current, and
in which the voltage across the terminals is directly proportional to
the current, as in the case of incandescent lamps, ohmic resistances,
etc., ammeters of the second class or dynamometer type should be
used.

If a meter of the first class and one of the second are connected
in series in a rectified current circuit, their indications will differ
according to the relation which the ripple bears to the total current,
and the form·factor. This discrepancy may be in the neighborhood
of from two to five percent under commercial operating conditions,
as shown by actual tests. The upper limiting value of the error
would be equal to the form factor, or ratio between the square root
of the mean square and the average value of the wave. In the
case of a sine wave this amounts to 1.11, causing an error of 11
percent in the reading. The same is true in a rectified sine wave,
starting from O, as shown in Fig. 2. It is evident that in rectified
current circuits, which have waves that do not touch the zero line,
as in Fig. 1, so great an error due to this cause could not be ob-
tained. Alternating-current ammeters operating on the induction
principle will measure with perfect accuracy the square root of the
mean square or effective value of the ripple only, and will not be
affected by the main portion of the rectified current.

THE JOURNAL QUESTION BOX

318—POOR OPERATION OF MOTOR ON OVER-VOLTAGE — Difficulty has been experienced in getting satisfactory operation with a 10 hp, shunt wound, 220 volt motor, the normal speed of which is 1 275 r.p.m. It is a four-pole machine with only two brush holders. It is operated from a circuit the normal voltage of which is 220 volts but which is boosted to 300 volts. With the motor operating on this higher voltage, the speed reaches 1 850 r.p.m., but on reducing the voltage to 220 volts the speed obtained is about 1 600 r.p.m. Upon operating the motor on various voltages, the field being connected across the 300 volt circuit, it has been observed that when the voltage is raised gradually the speed increases about in proportion until a voltage of about 200 volts is reached, when the speed suddenly rises to a value considerably above normal, where it remains fixed. The action is the same on no-load and full-load. The operation is accompanied by serious sparking and all conceivabel schemes have been tried without success, except that of increasing the pressure on the brushes. The result of too great pressure is, however, that the commutator gets very hot. The commutator is very wide and the segments are thin. Probably the high commutator speed has something to do with the sparking. Please suggest how satisfactory operation can be obtained.   E. L.

The machine evidently has never run within 25 percent of its rated speed, which might be caused by defective field coils or abnormal air-gaps. Careful inspection should be made to see that the air-gaps are uniform under the respective poles and that the poles are evenly spaced. One of the field coils might be partially short-circuited, due to an internal breakdown of the insulation. This can be determined by taking the drop across each field coil with a volt-meter, or after the motor has been running long enough on the 300 volt circuit to get warm, the temperature of the respective coils should be determined with the hand. A short-circuited coil will be cold. Another possible source of trouble is a reversed field coil. This can be determined by means of a compass or by testing with an iron bar to see that adjacent pole faces are alternately of positive and negative polarity. The excessive speed would tend to cause sparking. Too great current density in the brushes, that is, insufficient brush area, might result in sparking. Too great a back shift to the brushes would also cause high speed and excessive sparking. Difficulty from this source would be eliminated by shifting the brushes forward a small amount. With the field circuit connected directly across the 300 volt circuit the speed of the motor should increase proportionately as the impressed voltage on the armature is increased. Vibration or chattering of the brush holder will also cause sparking; this can be remedied only by changing the design of the holder or perhaps replacing the two-arm holder by a four-arm holder. This latter would have the advantage of increasing the brush area, thereby decreasing the current density in the brushes. A rough commutator caused by high or low commutator segments sometimes results in otherwise unaccountable speed variation. Trou-

ble from this source can easily be detected by resting the finger on the top of one of the brushes when any jumping of the brush due to unevenness of the commutator will be made very evident. A rough commutator can be corrected by turning down or by grinding with a sand stone. Excessive tension on the brushes is, of course, a poor way to overcome sparking, as the remedy may lead to worse results than the disease. A fibre graphite or a pure graphite brush might be found to overcome the sparking trouble. Too great an air-gap may be remedied by shimming the field poles; care should be exercised, however, so as not to add too much metal to the pole pieces, leaving insufficient clearance between pole faces and the armature iron, as serious mechanical trouble might result. See article on "Problems in Commutation" by Mr. Miles Walker in the JOURNAL for May, 1907,

<div align="right">L. A. M.</div>

319—DETERMINATION OF AVERAGE MOTOR LOAD—In order to find the average load on a single- or polyphase motor, would there be any objection to the use of a wattmeter connected in the motor circuit for the purpose, the power in watts being calculated from the formula $W = R \div T \times K$, the values of R and T being determined by counting the number of revolutions of the disk for one minute or any given length of time? Would not this test give almost as accurate results as though a portable instrument were employed, provided it were used in connection with an installation in which the load was nearly constant during the test?

<div align="right">A. G. G.</div>

Yes. The number of revolutions should be counted for approximately 60 seconds, using a stop-watch. With unsteady load, this method of determining average load would probably be found to be more accurate than that using portable meters, and on steady load it would be just as accurate.

<div align="right">A. W. C.</div>

320—METHOD OF CONNECTION OF BOOSTER TRANSFORMER — A 2 200 volt, primary lighting cir-

cuit on a local distribution system was subject to overload during the period of evening peak, the current varying between 25 and 35 amperes. It was decided to install a 7.5 kw transformer which could be used at time of overload to boost the voltage. The arrangement first tried was similar to that shown in Fig. 1 of article on "Alternating-Current Potential Regulators" by Mr. Geo. R. Metcalfe in the JOURNAL for August, 1908, p. 450; that is, the primary of the booster transformer was connected directly across the 2 200 volt line and the secondary was connected in series on the *load* side. With this arrangement, the voltage was, of course, boosted 10 percent. An arrangement was then tried in which the secondary of the booster transformer was connected in series on the *generator* side, when a further boost was obtained. We could not determine the exact value of the resulting voltage, as the reading went off the scale of the voltmeter. The ratio of transformation is 10 to 1. What is the exact voltage obtained with the second arrangement of connections? What is the phase relation of the secondary with respect to the primary? Is not the connection first referred to equivalent to that of an ordinary auto-transformer?

<div align="right">R. S. W.</div>

The arrangement first referred to is obviously equivalent to that of an ordinary auto-transformer. The value of the voltage obtained by means of the second arrangement of connections referred to may be calculated as follows: Let x equal the resulting voltage on the load side of the booster transformer. Then $x \div 10$ equals the increase in voltage due to the secondary of the booster transformer, as the ratio of transformation is 10 to 1. Then $x = 2\,200 + x \div 10$ or, $10x - x = 22\,000$. Then $9x$ equals $22\,000$, or $x = 2\,445$. The reason that a higher voltage is obtained with the second arrangement of connections is that, in this case, the volt-

age impressed on the primary of the booster transformer is the sum of the primary line voltage and the voltage of the secondary of the booster transformer, the result being a somewhat larger secondary voltage as a result of this increased primary voltage. As with any transformer, the primary and secondary voltages are at 180 degree phase relation to each other, hence, with the second arrangement under consideration, it is essential that the proper connection be made in order that the secondary voltage shall serve to raise the resulting voltage—with the primary and secondary operating in opposition, the effect would be to decrease the resulting voltage instead of raising it.   A. P. B.

321—GROUNDING OF DISTRIBUTING TRANSFORMER SECONDARIES—A 2 100 volt, three-phase, distributing system supplies 110 volt load, balanced on the three-phases by means of single-phase pole type transformers. It becomes necessary, for personal safety, to ground one side of each transformer secondary circuit as the transformers are not provided with neutral leads; does it make any difference which side is grounded?   T. L. M.

It is always preferable to ground the neutral of a transformer; if a neutral tap is not available, either side of the low-tension winding may be grounded. A definite rule should be followed in doing this, however, for sake of uniformity.   E. G. R.

322—METER EQUIPMENT REQUIRED IN CONNECTION WITH ALTERNATING-CURRENT MOTOR AND LIGHTING LOAD — What alternating-current instruments would be required for a factory equipment of twenty induction motors, six overhead cranes and a lighting load operated from a 220-volt, three-phase, 60-cycle circuit, the power being purchased? There are, of course, three single-phase wattmeters on the lighting board and a three-phase wattmeter on the power board, but no portable instruments have so far been provided.   C. A. M.

It is not stated whether only portable or both portable and switchboard instruments are wanted. It is better to determine the instruments after the general layout of circuits is made, but a rather complete equipment of instruments, with which all the ordinary measurements that would be required may be obtained, would be as follows:

Switchboard Instruments — Wattmeters referred to may be indicating, integrating, graphic recording, or both indicating and integrating. The three-phase wattmeter should preferably be connected so as to measure the total power intake. In addition to the *three* single-phase wattmeters on the lighting board and *one* polyphase on the power board, there should be provided *one* ammeter with *two* series transformers and *three* ammeter plug receptacles—all of this for each motor circuit and the same for the crane circuit; *three* ammeters and *two* transformers for the lighting circuit (use same transformers as for single-phase wattmeters); *one* ammeter with *two* transformers and *three* ammeter plug receptacles for the "total power" circuit (use same transformers as for polyphase wattmeter); *one* three-phase power-factor meter for the total power circuit (use with same transformers as for ammeter); *one* 300-volt voltmeter.

Portable Instruments—*Two* series transformers of each size from the minimum to the maximum current that is to be measured; for example, if the current to be measured varies from 10 to 400 amperes, *two* transformers each of 10-20-40 amperes capacity and *two* of 100-200-400 amperes capacity would be sufficient; *one* or *two* 5 and 10 ampere ammeters; *one* 300-volt voltmeter; *one* 5 and 10 ampere, 100 and 200 volt polyphase wattmeter; *one* 200-volt polyphase power-factor meter. This equipment includes only measuring instruments, protective or automatic regulating apparatus not having been considered.   H. W. B.

323—CAPACITY OF CARTRIDGE FUSES —Ribbon and string fuses are ordinarily marked as of a certain capacity when used in stated lengths; for example, a given size of fuse wire is mark-

ed 30 amperes when used in a clear length of four inches between points of attachment. In the case of cartridge fuses, what difference does an increase or decrease in the length of this piece make in the carrying capacity? What is the principle involved?   C. A. M.

The principle involved is the cooling of the fuse wire by the terminals by conduction through the body of the fuse; this is the same with both enclosed and open fuse. The longer the fuse the less it will carry; when a certain distance is reached, however, greater length does not make much difference and this critical length depends on the cross-section of the fuse, it being greater as the cross-section increases. Enclosed fuses are made of two lengths, one for 250 volts and a longer one for 600 volts. This is not on account of the varying capacity, but to get the necessary arcing distance between terminals, which of course depends on the voltage.   F. W. H.

324—OPERATION OF MINE HOISTS BY ELECTRIC MOTORS—I have had difficulty in following the details of the hoisting service described by Mr C. V. Allen in his article on the "El Oro Mining Company's Equipment," which appears in the June issue of the JOURNAL, and would therefore appreciate receiving a wiring diagram of this installation.   J. R. W.

A diagram showing the essential features of a fly-wheel equalizer set which operates on practically the same principle as this equipment is given in an article on "Electric Drive in Iron and Steel Mills" by Mr. W. Edgar Reed, in the JOURNAL for December, 1907, Fig. 2, p. 687.

325—TEST FOR AUTOMOBILE BATTERY—Automobile men have a method of judging the worth of a battery by measuring the voltage and the short-circuit current; for instance, they say that a battery for a spark coil should give six volts and sixty amperes. Is this test of any value; if so, why?   W. O. M.

If a dry battery is referred to, this method applies, but the test should not be continued for any length of time because of the rapid deterioration liable to result.

Methods of testing the condition of storage batteries are given in an article by Mr. W. A. Warfield, on "The Care and Maintenance of Storage Batteries" in the JOURNAL for August, 1908. The common standard way of designating the capacity of a storage cell is to state the number of ampere-hours which the cell will give, at a uniform rate of discharge of eight hours duration, between the limits of its full charge and the condition of discharge. This latter is an arbitrary value which is assumed to be indicated by the voltage of the cell; thus when the voltage of a battery in normal condition reaches a value of 1.75 volts per cell, it is considered to have reached the minimum discharge point. It is disastrous to storage batteries and most dry cells to discharge them on short-circuit for any length of time. The ampere capacity of a dry cell is such that, in order to obtain a discharge current of sixty amperes, a number of the cells would have to be connected in parallel. A short-circuit on a storage battery is apt to be more dangerous than on a primary cell, as the internal resistance of the latter is usually much higher. A short-circuit on a storage cell results in rapid deterioration of the negative plates. The effect on a dry cell is to cause polarization of the positive plate.   A. B. R. and W. B.

326—DETERMINATION OF INDUCTION MOTOR CONSTANTS — How should the following constants of the induction motor be obtained from the excitation, impedance, and resistance reading:—primary exciting conductance and susceptance, primary resistance and reactance, and secondary resistance and reactance? Will you also give me some references bearing on the design of alternating-current and direct-current machines?   H. F. H.

The conductance and susceptance may be found from the following formulas:

Conductance, $g = \dfrac{Ie}{E} = \dfrac{Ioo}{E} \cos \Phi$
(approx.)

Susceptance, $b = \dfrac{Im}{E} = \dfrac{Ioo}{E} \sin \Phi$
(approx.)

in which

Ie = no-load energy current per phase;

Ioo = total no-load current;

Im = wattless component of no-load current;

E = impressed e.m.f. per phase, and

Φ = angle of lag at no-load.

For a Y-connected machine the primary resistance per phase is one-half of the resistance measured between leads; for a delta-connected motor it is 1.5 times the measured value. The impedance, z, per phase = (volts per phase) ÷ (amperes per phase). Primary + secondary resistance per phase = (impedance watts per phase) ÷ (current per phase)^2 = r. Secondary resistance = (total resistance — (primary resistance). Total reactance per phase = $\sqrt{z^2 - r^2} = x$; the watts per phase equals (total watts) ÷ (number of phases). The following books on this subject are suggested for your further information: On alternating-current motor design, "Elements of Electrical Engineering," by Franklin and Esty, or "Alternating-Current Phenomena," by Chas. P. Steinmetz. On design of dynamo-electric machines, the following may be suggested: "The Dynamo," by Hawkins and Wallis; "The Electric Motor," by Hobart. I. E. H.

327—TRANSFORMER DESIGN — With data as to capacity, primary and secondary voltage, number and ratio of turns, weight of iron, area of magnetic circuit, etc., of a transformer to be designed, the substitution of these quantities in formulas found in different handbooks seems to give erroneous results. For example, on page 446 of Foster's Handbook (1908), the following formulas are given: $\phi = E \times 10^8 \div 4.44 \times N \times T$, $A = (E \times 10^8) \div 4.44 \times N \times T \times \beta$. Substituting known values for a 25 kw transformer —viz., primary voltage 10 000; secondary voltage, 220; primary turns 1 540; secondary

turns 39—results obtained for ϕ and A are out of all reason. Please point out the discrepancy. D. C. McK.

The difficulty is probably due to a very common mistake of confusing c.g.s. and practical units. For example, the value of β (flux density), is about 11 000 lines per sq. cm. or 71 000 lines per sq. inch in practical units. Considering the data for a 25 kw transformer with 1 540 turns, high-tension, the low-tension turns would be 34 times instead of 39. Substituting in the formulae: $\phi = (E \times 10^8) \div 4.44 \times N \times T = (10\,000 \times 10^8) \div 4.44 \times 60 \times 1\,540 = 2\,420\,000$; $A = (E \times 10^8) \div 4.44 \times N \times T \times B'' = \phi \div \beta'' = 2\,420\,000 \div 72\,000 = 34.3$ sq. inches. These are very reasonable figures. If the iron is worked at a lower density a larger core will be required. I. E. C.

328—METHOD OF RATING INTEGRATING WATTMETER—What is the value of the constant K in the formula, Watts = 100 RK ÷ T for the Stanley meter? The rating given on the meter is, for example, "50 Amps.—Two-wire—200 Secs.—60 Cycles—220 Volts — multiply by 10." The number preceeding "Secs." apparently varies according to the size of the meter. This may be the value of the constant K; but what does it really mean? A. R. T.

The value of "Secs." indicates the capacity of the meter. It represents the period of time required for one revolution of the disc on 100 watts. Hence, in the formula, the value of K is determined by substituting for W a value of 100; for R, a value of 1, and for T, the number of "Secs." as given in the rating of the meter.

A. W. C.

329—REVERSAL OF WATTMETER ON LOW POWER-FACTOR—Why does one of the two wattmeters in the two-wattmeter method of three-phase power measurement reverse its direction of rotation, giving negative reading, when the power-factor of the circuit is below 50 percent? W. P. F.

This is explained in an "Experience On The Road" article by Mr. M. H. Rodda, in the JOURNAL for July, 1909, p. 436.

330—MEMBERSHIP IN A. I. E. E.—
I would like to know the requirements for membership in the American Institute of Electrical Engineers or how I can become a subscriber to the Transactions or at least secure periodical copies of the Transactions. Please inform me also where I can get the Transactions.   J. D. N.

There are two grades of membership—associate and members. All applicants must first be elected to the grade of associate. Application for transfer to the grade of member may be filed at the same time, however, as the application for election as associate. The entrance fee is $5.00. The annual dues are $10.00 for associates and $15.00 for members. A fee of $10.00 is paid on transfer to the grade of member. The requirements for admission as associate, as defined in the Institute constitution, are as follows: "An associate shall be a person, not less than twenty-one years of age, who is interested in, or connected with, the study or application of electricity." Application should be made on a form provided for that purpose, a copy of which may be procured at any time from Mr. Ralph W. Pope, secretary of the Institute, 33 West 39th street, New York City. Three references are necessary, preferably members or associates of the Institute. The requirements for transfer to the grade of members are more exacting. The applicant, according to the Constitution, must be not less than 27 years of age, and must be a professional electrical engineer, or a professor of electrical engineering, or a person who has done important original work of recognized value to electrical science, or a person duly qualified as an engineer in an allied branch of engineering and who for a period of two years has had responsible charge of electrical engineering work, and whose professional record indicates that he is competent to design, as well as direct, electrical engineering works. To be eligible as professional electrical engineer the applicant shall have been in the active practice of his profession for at least five years; he shall have had responsible charge of work for at least two years, and shall be qualified to design, as well as direct, electrical engineering works. To be eligible as a professor of electrical engineering he shall have been in responsible charge of a course of electrical engineering at a technical school of recognized standing for a period of at least two years. Applications for transfer must be made upon a form which may be obtained from the secretary. The publications of the Institute are the Proceedings, published monthly, and the Transactions, published annually. The Transactions contain the engineering papers and discussions previously published in the monthly Proceedings and which in the meantime have been further edited and revised. Non-members may subscribe to the Proceedings or purchase the Transactions on application to the secretary. The subscription price of the Proceedings is $10.00 per year. The cost of the Transactions is $10.00 per volume in paper, or $11.50 in cloth binding. Institute members are entitled to these publications for the period covering their membership.   R. W. P.

331—SINGLE-PHASE LOAD ON THREE-PHASE ALTERNATOR—A 3 000 kw, three-phase, 4 000 volt revolving field generator has its dampers made in two parts, forming a butt joint at the center line of the field poles. Why is it that these dampers heat excessively, and fuse the metal at the joint, when the generator delivers single-phase current?   R. F. H.

This is accounted for by the fact that the armature reaction of a single-phase load is pulsating in character, thus causing increased eddy current losses, particularly in any solid metal parts such as the dampers mentioned. To obviate troubles from this source, alternators designed for single-phase operation have very low resistance dampers of sufficient heat capacity to neutralize the pulsating armature reaction without dangerous temperature rise. See article on "Modern Development in Single-Phase Generators" by Mr. W. L. Waters in the Proceedings of the A. I. E. E., May, 1908, p.579. F. D. N.

THE ELECTRIC JOURNAL

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THE ELECTRIC JOURNAL
Box 911, PITTSBURG, PA.

A Recent Improvement in Transformer Construction

Transformers require less attention than nearly all other kinds of electrical apparatus. They are usually complete and self-contained, although air-blast transformers are a partial exception, as the air-blast apparatus is generally separate and requires some attention. Such transformers should be kept free from accumulation of dust and dirt, and careful inspection should be made at cleaning time.

Water-cooled transformers must be supplied with proper water while in service, but they will usually carry their load for a short time without water; this depends upon the design. Occasional inspection of the cooling coils, windings and terminals should be made. If the units are out of service in very cold weather, the cooling coils should be freed of water to avoid freezing and bursting.

Self-cooling transformers stand alone; they are always ready for any load within their capacity. They do not need any air blast or cooling water when carrying load. They do not require any care when starting up or when being removed from service. The infrequent inspection properly given all apparatus to make sure that it is in order, is all the care required. Self-cooling transformers are built with practically the highest obtainable efficiency, in order to minimize the amount of heat which must be dissipated. This permits the smallest cooling surface and, consequently, tanks of minimum size and weight.

Until very recently the usual limit of capacity for a self-cooling transformer has been approximately 500 k.v.a. For a given floor space and height, 25-cycle, high voltage units have the smallest, and 60-cycle, low voltage units the largest capacity of standard frequency transformers. Transformers of 300 k.v.a. capacity for 25-cycle, 60 000-volt service and 650 k.v.a., 60-cycle, 11 000-volt units have approximately the same dimensions and have heretofore represented the approximate limits in self-cooling transformer construction. Transformers of the self-cooling type of 1 000 k.v.a. capacity and for 100 000-volt service, such as those described in the article by Mr. McConahey in the present issue, point the way to applications which so far have appeared to be unsatisfactory and ex-

pensive or even doubtful. Of course, few systems now employ 100 000-volt, 1 000 k.v.a. units; these transformers are more especially a notable example of the advance in self-cooling transformer construction. Self-cooling transformers of this type for 2 000 k.v.a., or larger, capacity and lower voltage may be built; for example, the tanks for the 1 000 k.v.a., 100 000-volt transformers would serve very well for 2 000 k.v.a., 11 000-volt, 60-cycle units. This is an increase of nearly four-fold over the recent capacity limits of this type of transformer. The determining factor which previously fixed the limit of size in which the self-cooling transformer could be built was the problem of obtaining a transformer case of reasonable dimensions, weight and cost. If the usual corrugations of the transformer case surface were made deeper, the area would be increased but the new surface would be practically useless for cooling. It would be at the depth of a corrugation already very deep, and hence would not be well exposed. The plain tank is the most effective for a given exposed cooling area. In the new type of construction the radiating power of the case has been greatly increased. The surface of the radiating tubes is essentially as good as that of the plain tank, inch for inch, and better than that of the corrugated case of corresponding size, in which the total exposed area is neither as large nor as well disposed.

The maintenance cost of water-cooled transformers, except at water-power plants, is usually considerable and sometimes even prohibitive. The attendance on self-cooling units is practically nil under all conditions of climate and service. For out-door service a self-cooling unit is particularly well adapted, because of the small amount of attention required. In very cold weather, with little or no load, the oil may congeal but, whenever the usual heat is reestablished, the oil will resume its normal consistency and recover any slight loss in insulating quality which it may have suffered when congealed. The fact that a type of transformer involving practically no attention or maintenance cost, and yet operative under all conditions of service, may be obtained is an important consideration. In many places this is essential; notably for stations operating long haul, single-phase railway systems where the high voltages involved prohibit the use of air-blast construction, and where no water is available for cooling purposes. The large thermal capacity of oil-insulated transformers is frequently of value in caring for overloads such as are common in railway traffic. The very high efficiency of self-cooling transformers

enables them to carry such overloads even better than the water-cooled type.

One of the notably attractive and valuable features of the modern oil-insulated transformers of both the water-cooled and self-cooling types up to about 1 000 k.v.a. capacity is the provision in the design for shipping the units sealed in their cases with oil. The saving effected by eliminating the drying-out process at the point of installation can hardly be overestimated.

K. C. RANDALL

Scientific Illumination Made Easy
It is interesting to observe critically the evening lighting of show windows which one may have been accustomed to observe in a casual way. Some such windows will be found with lamps which are throwing twice as much light into the observer's eyes as they are upon the goods to be exhibited. Not only is the light wasted, but the lamp instead of the exhibit is the prominent feature and the eye is so blinded that it is difficult to see the dimly lighted goods. This is not hypothetical, it is actual.

In other cases, rooms or areas to which one may have been accustomed for some time without thought or criticism of the lighting, are found upon a little analysis to violate the elementary and almost axiomatic principles of good lighting. The writer recalls a certain room which, after deliberate consideration, was provided with a novel arrangement of lighting. He was, at first, much pleased with the unusual effect produced. However, certain principles of illumination had been violated, as was evidenced by the eye fatigue resulting from looking constantly at a speaker who was only moderately illuminated while a bright wall threw a tiring light at an angle.

Illuminating engineering is difficult because it is physiological as well as physical, and often because of its psychological elements. It is not merely a question of the physical character and distribution of the light, nor yet its effect upon the eye. There is in addition to all this the matter of sentiment. Most people have quite a positive idea with regard to what is a good light and what is not, and these opinions are often quite irrespective of the real merits of the case. Any change from individual to general lighting or in the character or color of the light is often strongly objected to from personal prejudice, notwithstanding common sense or the experience of others. Many people are apt to form a judgment by looking at the lamp itself and considering a bright light or a pleasing form

as being inherently excellent. The wiser judgment is based upon observation of the objects to be illuminated. In show window illumination, for example, it is the goods rather than the light, and the light rather than the lamp which should attract attention.

Scientific illumination is difficult in itself. The inherent laws of light do not always lend themselves to the needs of the particular cases, and when the additional difficulty of erratic personal preference is added, the problem becomes peculiarly difficult.

Those who have given but incidental attention to the general matter of artificial illumination are liable to be much surprised, on reading articles such as that by Mr. Sweet, in the last issue of the JOURNAL, to find how many simple and obvious principles they have been in the habit of overlooking. The paper points out the impracticability of securing an illuminating engineer to handle each installation and shows that it is desirable to lay down principles and rules which can be directly applied by those who may have no technical knowledge of the subject. He has laid down simple, practical rules which summarize theory and experience in certain typical cases. These rules, covering the use of tungsten lamps for ordinary applications are given in the present issue; they do not involve logarithms, nor even a slide rule—a foot rule is sufficient.

CHAS. F. SCOTT

Who's Who in The Journal, 1909

The 169 questions printed in the JOURNAL Question Box in 1909 have come from 28 states and seven foreign countries. Canada leads the list; Pennsylvania follows. Questions have come from England, Germany, France, Japan, Hawaii, New South Wales and New Zealand. These questioners aid materially in the perennial problem of selecting interesting subjects, and they generally do it by bringing forward topics about which they really want to know something. The real difficulties and perplexities which have come to one are apt to come to others as well. Hence the topics are vital. One may see this for himself by running over the titles of the questions in a few issues and noting how many are real problems and how few are not worth while.

The answers have come from 75 men, each selected because he is particularly qualified to answer the particular question. These men are virtually assistant editors; they are an expert staff of specialists. Many of them have neither the time nor the inclination to write a lengthy article, but they can give a definite answer to a

concrete question. Many of the answers contain the meat of an article, without the introduction and conclusion, which is a relief to both writer and reader. The replies are not abstract; they are personal, and are signed by initials; they are sometimes mere facts, and sometimes professional opinions based on experience, which are often of more value than textbook data. The names of those from whom replies have been received are given on another page.

The Question Box is a sort of clearing house through which the man anywhere secures access to the man who knows, and often to one of the very few men in the country, who has exceptional knowledge or experience on the point at issue. The JOURNAL thus sustains a unique relation between its readers and writers. The part which its readers are now taking by their interest in the Question Box is making the magazine more definite and useful. It is planned to allot considerably more space for the questions and answers during the coming year, as the number of questions and answers published during the past year is a comparatively small percentage of the number actually answered.

The list of regular contributors, in accordance with the usual custom, is printed in this, the last issue of the current year. The fact that most of these men have done their work and done it well through their general interest in the JOURNAL, should be appreciated by its readers as it is by the management of the magazine, for they are not paid professional writers, but voluntary contributors, sharing in the interest and in the spirit which has animated the development of the JOURNAL by The Electric Club. It is thus the common co-operation of readers and of writers and of others who have given counsel and suggestion, which have together contributed to make the JOURNAL what it is.

The JOURNAL is now completing its sixth volume, and is well above 4 000 pages. Much of the material it contains makes it a good reference book for subjects which cannot be found elsewhere. A young man who recently took charge of the operation of the electrical apparatus for a large industrial plant said that he found the JOURNAL invaluable for its information and suggestions. When questions regarding apparatus with which he had had little experience or when new problems came up he referred to the Topical Index and usually found what he needed. As in former years, the JOURNAL will issue a topical index of all its volumes—a simple, six-year index will afford ready reference to what is virtually an encyclopaedia of up-to-date engineering information.

CONCRETE SWITCHBOARD STRUCTURES

L. B. CHUBBUCK

T HE use of concrete in switchboard structures dates back probably eight or nine years. Its use has rapidly increased until at the present time probably seventy-five percent of these structures are built of concrete. Its advantages over brick for this work are its greater strength and its more ready adaptation to the special forms of compartments and narrow barriers used for oil circuit breaker and bus-bar structures. Special narrow brick with deep recesses to give good mortar joints and help stiffen the wall have been used, but such brick is expensive, particularly if it has to be transported some distance to the plant. A common construc-
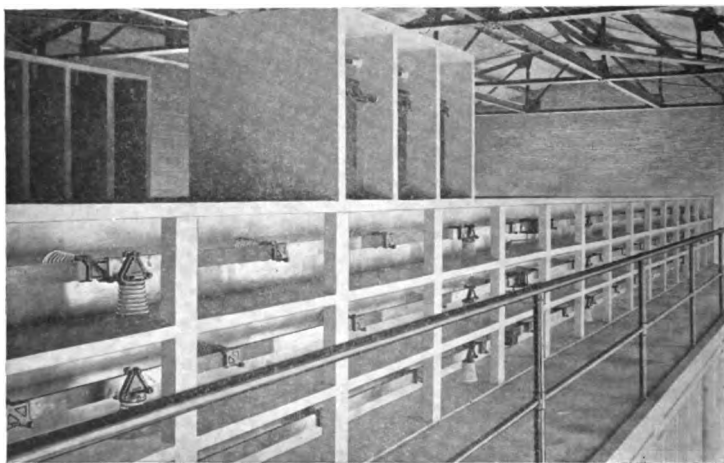
BUS-BAR STRUCTURE
Brunots Island power station, Pittsburg Railways Company.

tion has been to make the main walls, which are four inches or more in thickness, of brick or concrete and to use soapstone for narrow barriers and shelves. However, the main walls must be recessed for the soapstone and, as it does not form a good joint with cement or mortar, the structure is weakened. Where a considerable amount of soapstone is required in a structure the expense is quite an item. For the above reasons the all-concrete switchboard structure is now considered the best practice.

As examples of recent installations of this type, the accompanying illustrations, taken during construction, are given showing two

of the largest concrete switchboard structures thus far erected; one at the Youngstown works of the Carnegie Steel Company and the other at the Brunots Island power plant of the Pittsburgh Railways Company. The general layout of each of these installations is similar, each being a double-throw system and each comprising three tiers of structure. Both the cables leading from the generators and the feeder cables connect directly to the switchboard structure in the basement, compartments being provided therein for all of the series and voltage transformers except the bus transformers. Rising from the basement the cables branch, one set connecting through the circuit breakers and disconnecting switches of one structure to a corresponding set of bus-bars, while the second set of cables connects through a second similar structure to a corresponding set of bus-bars. The oil circuit breakers and disconnecting switches are located

CIRCUIT BREAKER FLOOR AND BUS-BAR GALLERY DURING CONSTRUCTION

Some of the expanded metal reinforcement and its supporting pipe framework is shown in position. The wooden forms are being set in place, wooden braces being employed as shown.

on the ground floor and the bus-bar structures on a gallery. This arrangement permits short direct electrical connections, a minimum of structure, with all apparatus and cables in compartments, but in full view and available for rapid inspection. This latter is important as apparatus located out of sight under false flooring, etc., very rarely gets any inspection.

In the Carnegie Steel station, the switchboard structures are

located in a bay along one side of the engine room, the control desk, panel boards, motor operated rheostats, etc., being located in the second gallery.

In the Pittsburgh Railways station the switchboard structures are located in a switching house, which is separate from the engine room. The generator connections are made by three conductor, 13 000 volt lead covered cables run in tile ducts. The iron conduits for the control and instrument cables run from the switching house to the engine room across reinforced concrete bridges. The control desk and instrument boards are located on an operating gallery at one side of the engine room.

The main walls of a concrete switchboard structure are usually poured in place between wooden forms, a common mixture being one part cement, two parts sand and four parts stone, the latter of about one-half inch diameter. Narrow barriers and shelves can be con-
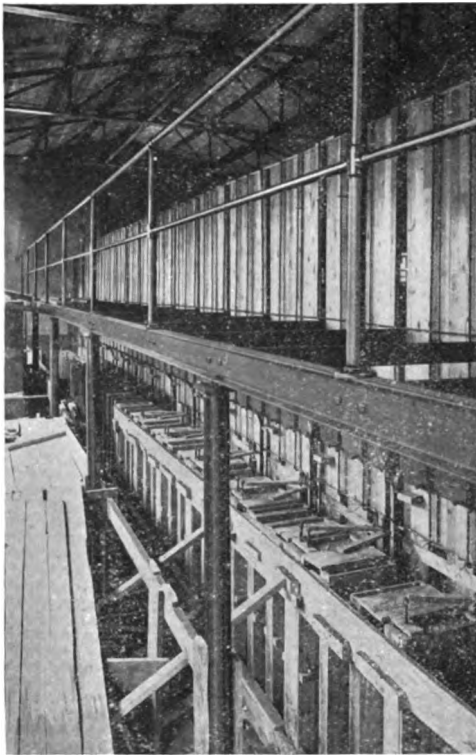
CIRCUIT BREAKER FLOOR AND BUS-BAR GALLERY—
FRONT VIEW

The circuit breaker barriers have been poured, some of the forms and bracing still being in place. The far side of the main wall forms are in place (shown from the other side in the previous illustration); the near side of the main wall forms to be erected five inches in front of these and the intervening space then to be filled with concrete.

structed by several different methods.

One method is to make these as individual slabs. Where reinforcement is necessary, on account of thinness and size of the slabs, the concrete is poured to one-half the total depth required, the reinforcement (usually expanded metal) is laid on and the remainder

of the concrete poured and leveled to the top of the wooden form. After the concrete has set hard enough to be handled, the slabs should be submerged in water, if possible, for several days, as this produces very strong hard slabs. The slabs are then set up with the forms for the main walls so that when the main walls are poured the slabs are cemented into them.

A second method of constructing the narrow barriers and shelves is to pour these in place in the structure, building wood forms for these in the same manner as the forms for the main walls. It is evident that the expense of the wood forms is much
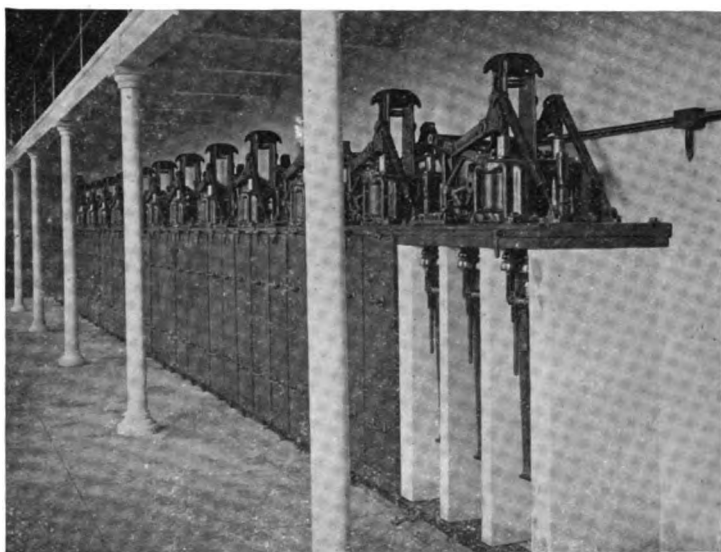
CIRCUIT BREAKER STRUCTURE COMPLETED—FRONT VIEW

The control circuits are carried in conduits set in place before the concrete is poured.

greater with this method than with the first method described above. On the other hand, this method makes the strongest and most homogeneous structure, no handling of the slabs is required and, for an installation of fair size, is probably as cheap as the first method. It is customary to set up the forms for a part of the total structure at one time, usually a section about sixteen feet long. After this section has been poured and has set long enough to stand without support, the forms are removed, refinished and used for the next section. The faces of the wood in contact with the concrete are refinished by cleaning and giving them a coat of linseed oil. At the Carnegie Steel plant, a small motor-driven planer was used to dress

the surface of the forms. No difficulty is encountered in pouring the vertical barriers except that care must be taken in working the concrete down into narrow barriers so that no spaces are left. Any reinforcement required can be given these narrow barriers by inserting square or twisted iron rods vertically in the center of the barrier as it is poured.

In the case of a large bus-bar structure with a number of horizontal s h e l v e s, the structure can be built up in several vertical sections, each of these sections being the height between shelves a n d each shelf being poured as in a tray. After this has set sufficiently the next higher section is poured. On account of the time required for each section to set, a quicker method is to build up the forms for the full height of the structure and pour all at one time, using very fluid cement. This was the method used at the Carnegie Steel plant. With this method,
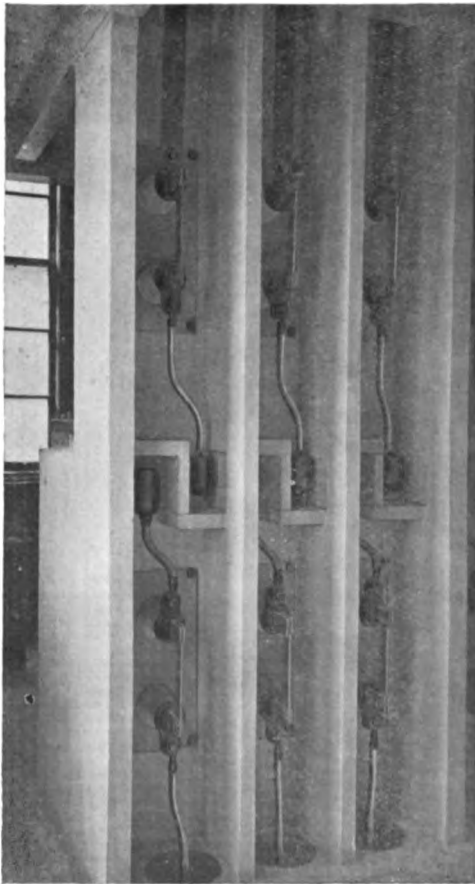
REAR VIEW OF COMPLETED CIRCUIT BREAKER STRUCTURE

Showing connections to circuit breaker terminals and disconnecting switches.

care must be taken in working the concrete into the shelves, and vent holes must be left to permit the escape of air. The wood forms between the shelves and barriers are so designed that no nails and only a few screws are required to hold them in

place, so that they can be easily erected and rapidly knocked down.

A third method, which is the one employed by the Pittsburgh Railways Company for constructing narrow concrete barriers and shelves, is to set up expanded metal formed to the exact shape of the barrier or shelf and plaster this with cement to the thickness required. A wood strip of the proper width is run up along the frame of the expanded metal and the plastering is run out flush with this strip. The cement is plastered on in several layers to the desired thickness. A suitable quantity of hair is mixed with the cement to give the necessary adherence, and a wooden backing is
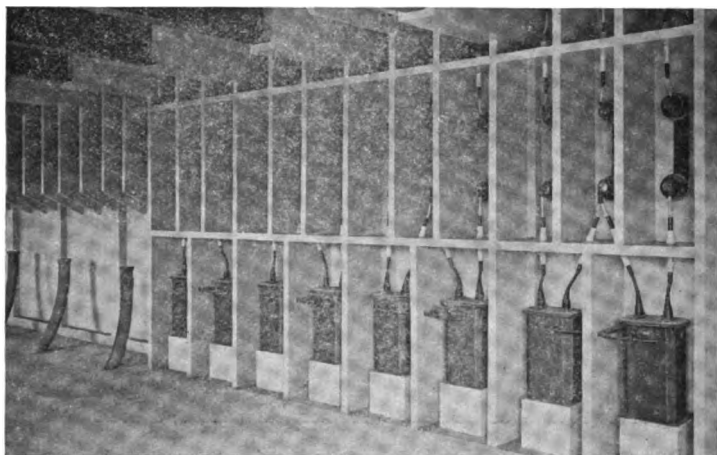
COMPLETED BASEMENT STRUCTURE FOR VOLTAGE AND CURRENT
TRANSFORMERS AND FUSES

This is directly beneath the circuit breaker structure shown in the foregoing illustrations. The high-tension leads are carried through holes in the floor above and porcelain insulating bushings are used in the walls of the structure. The secondary leads of the transformers are carried to the meters in the switchboard structure through conduits.

erected for each barrier on the opposite side to that which is being plastered to prevent buckling.

Any recesses required in the structure for switch bases, etc., are obtained by fastening to the inside of the wall of the wood form, dummy wood bases of the correct size, these bases being smooth and preferably oiled. When the wood form is removed these dummy bases come off with them, leaving the recess desired. Any anchor bolts, etc., required are also attached to the form, projecting into the structure the desired length. In this case when the forms are removed, the bolts remain in the structure. Where small holes
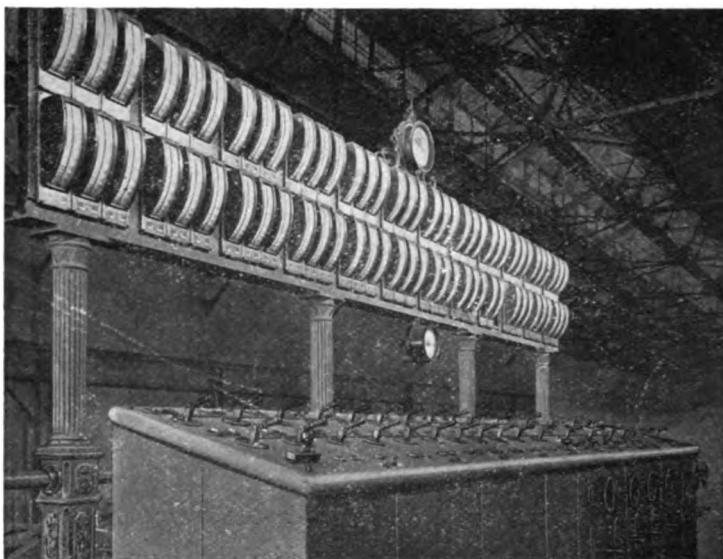
INSTRUMENT FRAME AND CONTROL DESK—PITTSBURG RAILWAYS COMPANY

These are located at the front of the operating platform under which are located the field switches and rheostats.

are required in the structure, stiff rubber tubing of the correct diameter can be used, this tubing being taken out afterward to leave
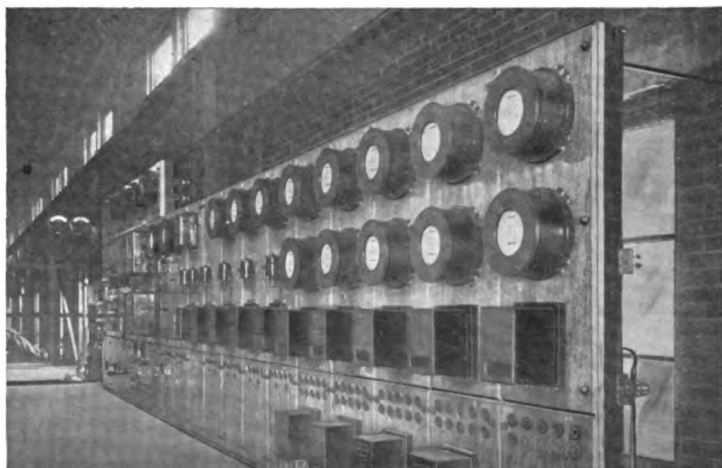
EXCITER AND RELAY SWITCHBOARD

Located at the rear of the operating platform, each panel being opposite its corresponding control panel and instrument frame (as shown in the preceding illustration),

the hole required. The iron conduits for the control and instrument cables are held in position inside the forms.

For the forms, carefully faced and oiled boards not less than one inch thick should be used. It is impossible to make a good structure from miscellaneous boards obtained from packing boxes, etc. On account of the great weight of concrete in such structures, it is usually necessary to brace the forms very carefully. Instances have occurred where, due to insufficient bracing, the forms have given way when nearly filled with concrete, with results that have
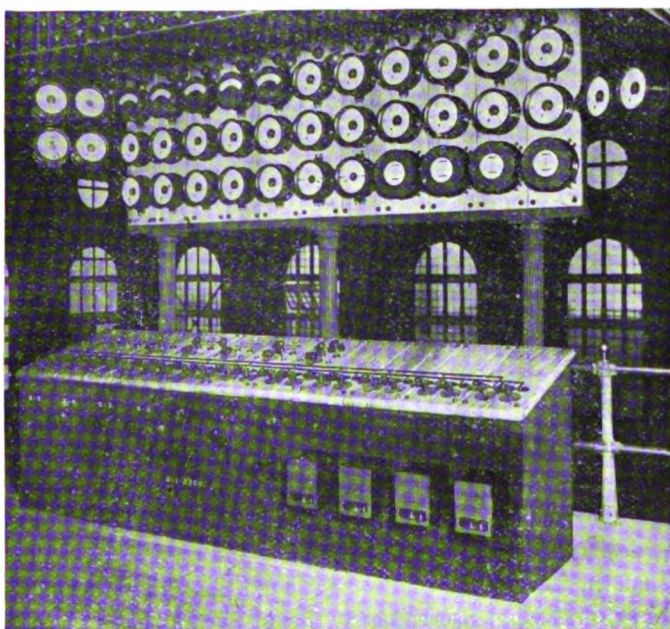
INSTRUMENT FRAME AND CONTROL DESK—CARNEGIE STEEL COMPANY
These are located at the front of the second gallery, the same arrangement as at the Brunots Island station, giving the operator a full view of the machines in the station.

to be seen to be fully appreciated. After the forms are removed, the structure must be kept wet for some time, keeping it thoroughly wet half the time for the first few days and after this twice a day for a couple of weeks.

The structure is finished by applying some form of wash or plaster. A dark cement wash, used extensively, gives the structure the appearance of slate. White plaster, applied very stiff, can also be used. This plaster is varnished with a white varnish so as to give a white glossy finish which can be cleaned by washing.

SOME PHASES OF ELECTRIC POWER
IN STEEL MILLS*

CHAS. F. SCOTT

A N observing engineer has remarked that the first object of
a steel mill electrical engineer is "to see that he holds his
job," and his job is "to get the tonnage out." Hence as the
job grows, the man must grow also. Large output requires that the
mill run and that it keep running.

Electricity in the steel mill is no longer an incidental feature,
it has become a fundamental method. The problem is no longer to
adapt a motor to run a minor part of the mill, but to adapt the whole
mill to the electrical system. The power-generating apparatus on
the one hand and the mill machinery on the other hand must be
fitted to the electrical system by which they are connected. The in-
troduction of electricity usually begins in a simple way, but it soon
produces radical and fundamental changes. In the steel mill the
electrical system has transferred the generation of power from a
scattered lot of engines, of various sizes and speeds and speed con-
trol, to a central power house, with large and efficient units. The
electrical system has changed from a small direct-current plant, to a
comprehensive alternating system, which must meet the double and
severe requirements of fluctuating load, and of continuity of service.
It has inaugurated new methods, it has given new possibilities to
the machinery which it drives, and presents new problems in engi-
neering design.

What then are some of the new conditions that the new situa-
tion brings, and what are some of the problems that now confront
the engineer? The writer does not presume to go too far in ad-
vising experts in a business in which he does not possess personal
experience, but proposes to present the observations of one who
views this subject at long range upon several topics having an im-
portant bearing upon the application of electricity in the steel in-
dustry.

THE REMOVAL OF LIMITATIONS BY ELECTRICITY

The methods and the results obtained in the steel mill have been
fixed by the steam engine. Its power has been applied either direct-

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*A paper read before the Association of Iron and Steel Electrical Engi-
neers, Buffalo, June, 1909.

ly or through gears and shafts. The distance between boiler and engine has been limited by the low efficiency of steam pipes, and the distance from the engine to its work has been limited by the low efficiency of mechanical transmission. In the electric system, the engine does not have to be located close to the work; it does not have to be reversed, nor does its speed have to be varied. This freedom enables the engine to be of such a type, size, speed and location as will secure the greatest economy in the production of power.

In the distribution of power, the removal of the old limitations by the substitution of electric wires, gives new possibilities for the general arrangement and disposition of the plant with a view to economy in handling the material without reference to local boilers and engines. But the purpose of the whole power system is to apply power. It is reasonable to expect that the introduction of the electrical system, although it has transformed the power plant and the distributing system, will effect far greater changes in the apparatus which it drives. A motor may of course simply replace an old engine and do the work which it did. This often neglects a greater opporuntiy. A motor is more suitable for driving a mill, not simply because it may do what the engine did, but because it can do what the engine could not do.

Why is the mill machinery made and operated as it is? Why is the general layout as it is? Why is the material handled as it is? In how far have these methods been fixed and determined by the driving power available, and wherein can they be improved if power limitations are removed and motors be furnished to meet ideal conditions? Such questions as these indicate the attitude which should guide the introduction of electric power. It opens a new field for constructive engineering imagination and design, in an industry most notable for its push and daring. Electricity has taken the engines out of the mill and put them in a power house; engines may now be larger and more efficient; they may be fed by waste gases instead of coal; may not the mill also be larger and more efficient?

THE COST OF POWER

To produce cheaper power by means of gas engines has probably been the controlling reason for the largest introduction of electricity in steel making. Important as this may be, the total cost of power is relatively small, say about five percent of the total cost of production. Other things, therefore, are of much greater consequence. Greater speed in operation; greater facility in handling

material; reduction of liabilities for break-down; increased rapidity in making repairs; reduction in labor costs—such items as these are far more important than power in making up the cost sheet. Hence, it is poor economy to economize in the quantity·or in the methods of applying power, if it be at the expense of something more important. Complicated or delicate apparatus, however high its efficiency, may be very expensive if it gets out of order easily. Effectiveness for service is of first importance in the power house, in the transmission system, and in the motors.

COST OF MOTORS

When two prices differ by hundreds or by thousands of dollars, the difference looks large, especially to the purchasing agent. Considered broadly, however, the first cost of a motor is the least important item. The annual fixed charge on an average motor, including interest, depreciation, sinking fund, and the like is not more than a few dollars per horse-power of its rated capacity. This is a small part of the cost of the power consumed by the motor, and is a very small part of the cost of the output, in many cases only about one percent. Therefore, if one motor is superior to another through its general sturdiness, its better speed adjustments, its quickness in reversing, the general convenience of its controling apparatus, or in any other particular, which will lead to the prevention of delays or to accelerated service so as to increase the output or reduce the labor charges, it is the kind of a motor to purchase, and one would be justified in paying double price for such a motor. Important as first cost may be, it is insignificant compared with ability for subsequent performance. It is well, therefore, to figure out the probable additional cost of repairs and the cost of the more probable delays which an inferior motor may cause, and compare the result with the difference between the first cost of the best motor and that of the cheapest motor.

SELECTION OF MOTORS

Interrupted service ruins cost and reputation. A motor break-down in one part of a machine shop, affects that part only, but in a steel mill it may affect all parts—furnaces, reheaters, locomotives, and in fact operation of the whole plant may be disabled. Hence, ultimate success depends largely upon the proper selection of electrical apparatus.

A motor is a part of the mill which it runs, be it a crane, or fan, or reversing rolls. They must be adapted to each other. In

simpler cases a standard motor having the necessary characteristics is selected. When a motor replaces an engine in an existing mill, the requirements are fairly definite. When a new mill is being designed then there is opportunity for mutual adaptation. The motor must be adapted to the work which it has to do, but, on the other hand, it should be a motor which is practicable to design and to construct. Sometimes a slight and incidental change in the design of a mill may simplify the motor and reduce the cost, both the first cost and the cost of maintenance. On the other hand, a slight change in the construction of a motor may aid greatly in applying it to the mill. Now the problems and characteristics of motor design are no better understood by the mill operator than are the principles of steel manufacture by the electrical designer; it is the steel mill electrical engineer who is the intermediary. It is not necessary that he be an electrical designer, but it is necessary that he consult freely with the electrical designer and work jointly with him. If such means be adopted motor designers are not liable to be called upon to produce freak apparatus to meet exacting conditions, when slight modification might have insured a better as well as a cheaper motor.

On the selection of motors, therefore, depends the possibilities of increased output by effective mutual adaptation of the motor and mill, of economy in the cost of production which may result from superior apparatus, from minimum break-down and greater facilities for repairs. The selection of the motor by which the power is to be applied is probably the most important duty of the electrical engineer. He bridges over between the mill and the electrical designer. The motor is the vital operating element of the mill. A power plant, the distributing system, the efficiency of apparatus, the cost of power — all these are subordinate to the proper application of the power and the proper selection of the motor. Hence, the man who selects a motor ought to be the man who knows, and has the courage of his convictions in applying the principle that the first cost of a motor is of trifling importance compared with ability to obtain a larger output, to operate continuously and to minimize general operating costs. If there is any place in which quality should outweigh initial expenditure, and in which the engineer rather than the purchasing agent should be supreme, it is in the selection of motors to operate steel mills. There is little glory in saving a hundred dollars when a motor is bought, but there is big blame when a break-down loses thousands. The

electrical man may not get the little glory, but he is sure to get the big blame.

THE USE OF ALTERNATING CURRENT

The concentration of power plants and distribution over large areas calls for alternating current. This in turn involves the use, either of alternating-current motors or of auxiliary apparatus for producing direct current. In making choice of methods the first cost and the operating cost should be determined, of course, but these should not obscure more important items. The alternating current is less familiar to mill men than the well established 250-volt direct current. The alternating-current motor is unlike its predecessor in appearance, construction and operation. It is different. Some features are much better, while in some places, others are not so good. The absence of commutators both in the generating and in the use of the current is a practical advantage of especial importance when the units are large. Auxiliary converting apparatus is objectionable in point of first cost, low efficiency, attendance and on the general ground that any additional apparatus with its auxiliary switching and controling appliances is to be avoided whenever possible. Common sense mechanical instinct will choose nothing but alternators and induction motors, the simplest kind of generator and the simplest kind of motor. Rotary converter, direct-current motor and synchronous motor are, therefore, all put on the defensive. They must show specific advantages, which will more than compensate for their disadvantages. Sometimes a modification in the method of operating may admit the induction motor under conditions in which at first it may have appeared impracticable to secure its simplicity and reliability.

THE QUESTION OF POWER-FACTOR

If an alternating plant were observed by wattmeters without the use of ammeters, a great deal of mental annoyance would be prevented. In many cases this would, in fact, be a good way to operate—provided the safe limits are not exceeded. The power-factor microbe is confined almost entirely to the electrical system. The work which the engine has to do, and the work which the motor does are scarcely affected. An induction motor requires a current of two kinds; one is the work current which affects wattmeters and produces horse-power; the other is a different kind of current—a magnetizing or exciting current, or, as ordinarily termed, wattless current. In a way it corresponds to the field or exciting current

of a shunt motor, which is additional to the work current applied to the armature, and which may be taken from the power generator or from an exciter. Likewise, the wattless current for the induction motor can be furnished by the power generator, or it may be supplied from another machine, such as a synchronous motor either running empty, or carrying load and which may be located in the power station or elsewhere on the system. In a given case, therefore, the problem is whether it is preferable to make the power generator large enough to supply the extra current, or to call upon a synchronous motor or compensator, located at a favorable point. In general the power generator should supply at least a part of the extra current by adapting it for, say, an 80 percent power-factor, which means that it can supply a full-load current 25 percent in excess of that which affects the wattmeter—in this case the wattless current may be 60 percent of the total. Even when the power-factor is lower, it will be simplest and often best to provide for the extra current capacity in the generator, but sometimes it is advisable to operate a synchronous motor or compensator. The choice depends largely upon the various local conditions, including the generator speed, the distance of transmission, and the convenience of utilizing power by synchronous motors.

If the generator speed be low, it may be cheaper to generate the extra current in a high speed auxiliary synchronous machine. If the distance of transmission be considerable it will relieve the transmission circuit of the idle current if it be produced in a synchronous machine near the load. If the extra current can be furnished by a working synchronous motor instead of an idly running synchronous compensator, the cost will be less. Sometimes the power-factor receives such profound consideration that it appears the all important element. It is veiled in mystery and is assumed to be a discreditable feature of the alternating-current system. Now it is true that the power-factor is an essential element of an induction motor; that the magnetizing and work currents do not add up by straight arithmetic, but by the right-angle triangle method, and that the less the magnetizing current (i. e., the higher the power-factor) the easier it is to provide for. But other apparatus have certain disagreeable features too. Direct-current motors have commutators and brushes; synchronous motors have separate exciters and small starting torque. It is apt to be considered quite proper to provide a motor-generator substation to supply the direct-current motors but quite a hardship to provide the generator capacity nec-

essary for the wattless current of induction motors. The conditions should be clearly recognized and squarely met by determining the relative cost and ability of the several methods to produce the magnetizing current under the particular conditions at hand. It is to be remembered that each induction motor requires a magnetizing current which is practically constant and a work current which varies with its load; that the work current of all motors may be added together to determine the total to be supplied by the power generator; that the magnetizing current of all motors may be added together to determine the total which must be supplied either by the power generator, or by a synchronous apparatus; that the total current at any point in the system is the resultant of the two currents and is proportional to the hypotenuse of a right-angle triangle of which the sides represent the two currents; and that the power-factor is the ratio of the work current to the resultant current.

Probably the simplest way to consider the power-factor condition in a given plant is to determine separately the total work current required and the total amount of magnetizing current. It will then be easy to determine whether the magnetizing current can be best produced in the power generator or elsewhere. It is to be remembered that the total current is not equal to the sum of the two components. For example, if one hundred amperes of work current is to be supplied and also one hundred amperes of magnetizing current, it will be necessary, if the two currents are supplied by separate machines, to generate one hundred amperes in each machine, but if both currents are produced in the same machine, the resultant will be 141 amperes. It is therefore seen, that it is desirable, other things being equal, to produce both kinds of current in the power generator rather than by separate machines.*

A comparison was recently made between two large induction motors of equal output, designed for different power-factors. It was found that in one case the magnetizing requirements were 500 k.v.a. for one motor, and 600 k.v.a. for the other motor on the basis of 1 000 horse-power output. The power-factors were approximately 75 percent and 82 percent respectively at three-quarter load, while they differed about two percent at full load. At partial load, therefore, the total current of one motor was but ten percent more than was required by the other motor, while at full load it was but two

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*An article on the "Rational Selection of Alternating Current Generators" by F. D. Newbury in THE JOURNAL for August, 1909, discusses the general subject of generator capacity and power factor.

percent. The difference in the cost of the two motors was approximately $2 per horse-power, or $2 000. The real question is, therefore, whether the saving of $2 000 will provide the extra k.v.a. of magnetizing current. Now, if the generator is a large one, and is working at high power-factor, the additional 100 k.v.a. will have but a trifling effect upon the total current from it, increasing the load by, say, ten k.v.a., instead of 100 k.v.a. On the other hand if the power-factor is already quite low, then the addition of the 100 k.v.a. will increase load on the generator by possibly 70 or 80 k.v.a. If the 100 k.v.a. is supplied from a synchronous compensator, the additional output required from it will be 100 k.v.a. The precise method to be followed depends, therefore, upon the local conditions, which control both the value of high power-factor in the motor and the method of producing the magnetizing current.

To sum up in a few words, the power-factor has little or no effect upon the engine or the work which the motor does, but is a matter incident to the electric system alone. If proper provision be made its effect should not appear in the mechanical operation of the apparatus. The power-factor should be provided for in the design of the electrical system and although the induction motor does require additional generating capacity, yet this can usually be provided and the system installed and operated more economically and efficiently than it could by any other class of apparatus; and it is simpler.

THE ELECTRICAL ENGINEER OF THE STEEL MILL

Usually a man who simply aims to "hold his job" is narrow and unprogressive and tends to fossilize, but the electric man in the steel business must be a good runner to keep up with his job. Years ago he trimmed the arc lights, then he ran the cranes—this made him an operating man—and as electricity becomes the operating method, his operating responsibilities grow.

With this broadening in the application of electric power, the mechanical man naturally feels the limitations due to ignorance of electrical matters. He is apt to progress more slowly in acquiring electrical knowledge than does the electrical man in acquiring mechanical knowledge. Mechanical knowledge can be more readily acquired by observation and experience than can electrical knowledge, which is more dependent upon a theoretical basis.

The advance, which should follow the introduction of electricity in improved methods and improved mill apparatus, depends largely upon improved methods of applying power. These are matters which

are not primarily electrical, but are closely connected with electrical application. The facility for doing things differently is one for which the electrical engineer is noted and in many industries he has suggested the new methods which have been made possible by his apparatus. He best appreciates the power problem and it is his function to take the initiative in proposing new apparatus and new methods, and adapting the electrical apparatus to produce the best results. Hence the electrical engineer is not passive, and does not merely carry out the instructions and meet the requirements of others, but he himself should be an originator.

Electricity is a heat producer as well as a power producer. For low temperatures electric heat is more expensive than fuel heat, but for high temperatures electricity, when the cost per kilowatt-hour is low, becomes relatively cheap, and it can be efficiently applied and controled. If the electric furnace will materially reduce the cost of open-hearth steel, the electrical engineer must become a furnace as well as a motor expert.

The character of steel manufacture is changing. Mr. Julian Kennedy, a few days ago, at the laying of the corner-stone of the Engineering Building of the University of Pittsburgh, said, "The success of the steel industry in the past has depended upon push, energy and daring; but in the future it will depend upon the economies and refinements of the art."

Look at the general situation; note the rapidity with which new methods are adopted in the steel industry, and the frequency at which previous records are broken. Put into an industry which has such push and daring, a new method of generating, conveying and applying power, and radical changes are sure to come. It may be difficult to predict just what these changes will be, or to fix a limit, but the conditions are auspicious, and evolution will follow. All this means that the electrical engineer in the steel mill is at the center of the new activity. He must take up the new problems from a broader point of view and in a new way. Electricity revolutionizes the power plant; problems of gas engines and steam turbines make him a power plant engineer; electric current must be carried considerable distances, and he becomes a transmission engineer; electricity drives the mill, and he must be a mechanical engineer; electricity heats the furnace, and he must be a metallurgical engineer; electricity is the operating system, and he is the operating engineer; electricity co-ordinates and unifies, it has to do so with methods, designs and constructions, and the electrical engineer becomes the general engineer.

MULTI-SPEED DRIVE BY INDUCTION MOTORS

A FEW SPECIFIC EXAMPLES

H. C. SPECHT

IN the past few years a pronounced demand has developed for multi-speed induction motors. It often develops that, for a given application, neither direct-current nor alternating-current commutator-type motors are entirely suitable, either due to difficulty in obtaining satisfactory commutation under severe operating conditions, or on account of the characteristics of the power system. A number of methods of varying the speed on induction motors have been described in previous issues of the JOURNAL,* which demonstrate the possibilities of this method of speed variation. Many applications require individual treatment in determining the exact details. It is sometimes advisable to combine two or more methods of obtaining multi-speed operation when the most economical, yet practical, arrangement is desired. In this connection the following examples of installations, in which some of these schemes have been applied, will be of special interest.

MULTI-SPEED DRIVE IN STEEL MILLS

The use of electric motor drive in rolling mills has been given a great deal of attention of late, resulting in the development of apparatus whereby better results have been made possible, at the same time effecting better economy of operation. One common method of accomplishing this may be outlined as follows: During the process of rolling, the rolls working on different sections require different speeds; the smaller the section the faster the speed required. In a mill which always rolls the same material and the same sections, the different speeds at the respective rolls are generally obtained by mechanical devices and sometimes, in addition, by two or more motors. A number of rolls for the first passes are driven by one motor, faster and slower speeds being obtained by speed changing devices such as pulleys and belt, rope drive, or gears. A number of the succeeding rolls are similarly arranged in group drive to be operated by a second motor, which may itself operate at a higher speed than that of the first motor. A drive of this character is illustrated in Fig. 1.

In a mill where different materials, different speeds and differ-

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*See articles by Mr. Specht in the July, August and October, '09, issues, pp. 421, 492, 611, respectively.

ent sections are to be rolled at various times, motors having differ-
ent speed characteristics are sometimes required or interchangeable
mechanical devices have to be employed. As indicated in the preced-
ing articles, already referred to, any scheme of obtaining various
speeds with induction motors has some drawback, either in regard
to simplicity or cost. The greater, the number of speeds required,
the more complicated becomes the design of the motor, the control,
and the switching auxiliaries. Moreover, the cost of such motor
outfits is higher, and it is not always convenient to obtain the exact
speeds which are desired. The necessity of most careful analysis
of the conditions to be met and the means whereby the desired re-
sults are to be accomplished is thus very evident. It may be said in
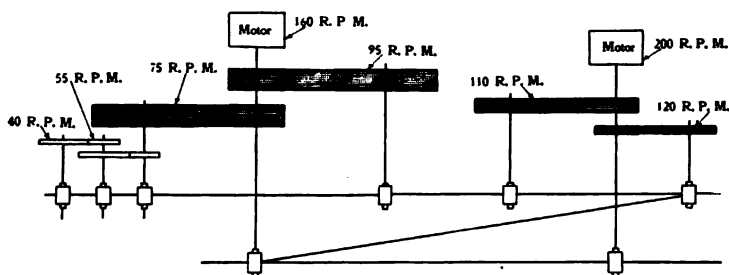
FIG. I—MULTI-SPEED ROLLING MILL DRIVE BY MEANS OF TWO CONSTANT
SPEED MOTORS

Mechanical speed changing devices are arranged in two groups, giving
progressive increase of speed on the rolls as required for the rolling of
a given material and given cross-sections.

general that it is desirable to limit the number of speeds and select
such speed ratios as can be obtained with the least complication
and lowest cost.

A motor-driven nine-inch merchant mill* at the works of
Messrs. Henry Disston & Sons, Tacony, Penna., serves as an ex-
ample of the practical solution of a specific case, such as that just
considered. A two-speed motor was selected for driving this mill
and rolling the different sizes and sections. The motor is connected
to the mill by belt drive. Its characteristics are as follows: 600
hp., 2 200 volt, 60-cycle, two-phase, operating at 600 r.p.m. (syn-
chronous speed) and 450 hp when operating at 450 r.p.m. (syn-
chronous speed). The arrangement of this mill is shown in Fig. 2.
The primary of the motor consists of two separate windings, one
for 12 poles and the other for 16 poles. The secondary or rotor of
the motor is of the ordinary squirrel cage type. The change of

*See paper by Mr. Brent Wiley, Proc., A. I. E. E., July, 1909, p. 773.

connections to obtain the speed desired is readily made by simple switching apparatus.

Another method of solution for induction motor drive is illustrated by a continuous mill at the works of the Pennsylvania Steel Company, Steelton, Pa. In this case 300 hp, 400-volt, 25-cycle, three-phase motor of the two-speed type is used, the speed corresponding to this output being 375 r.p.m. (synchronous speed). The output at the slow speed, 187.5 r.p.m., is 150 hp. The primary (stator) consists of concentric windings with an average throw corresponding to 16 poles. For high speed operation, cor-
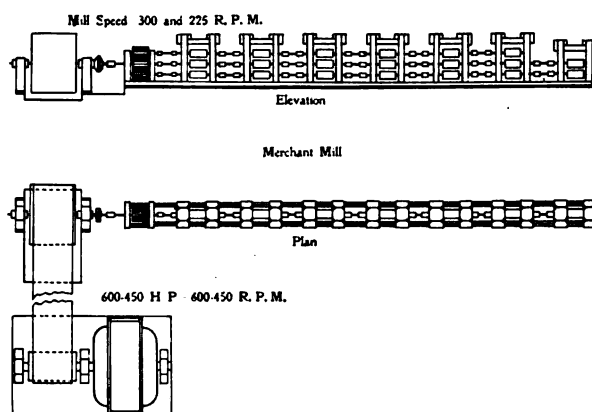
FIG. 2—MOTOR-DRIVEN MERCHANT MILL IN WHICH DIFFERENT MATERIALS AND VARIOUS CROSS-SECTIONS MAY BE ROLLED AT DIFFERENT TIMES

In this type of mill, provision must be made for more than one operating speed. The advantage of multi-speed characteristics in the motor over the use of interchangeable mechanical devices is obvious.

responding to eight poles, the primary winding is connected in parallel-star, while for low speed operation, or 16 poles, the winding is connected in series-delta. Six leads are brought out from the primary winding to the switching devices as shown in Fig. 3. For the delta connection the leads *a*, *b* and *c* are connected to the three-phase line, the leads *d*, *e* and *f* being disconnected. For the star connection, *a*, *b*, and *c* are connected together, and the leads *d*, *e* and *f* are connected to the line.

The secondary of this motor consists of two separate diamond coil windings, there being five collector rings provided, by means of which external resistance is introduced in the secondary (rotor) circuit, when required to give adjustment of speed for starting, etc.

One of these rings serves as a common connection for both windings. The winding in the lower part of the slots is for operation at the speed corresponding to eight poles, while that in the upper part of the slots is for operation at the lower speed corresponding to 16 poles.

Another notable example of the application of two-speed induction motor drive for rolling mill service is to be found at the Illinois Steel Company, South Chicago, Ill., where a large rail mill is operated by means of two identical cascade sets. The motors operate on a 2 200-volt, 25-cycle, three-phase circuit, the capacity of each set being 1 800 hp at 83.3 r.p.m. (synchronous speed) and 1 200 hp at 125 r.p.m. One motor of the set is wound for 24 poles and the other for 12 poles, the two rotors being applied on a common shaft. The motors are direct-connected to the roll spindle. A fly-wheel is also employed on the common shaft. To obtain the slower speed, the two motors of the set are connected in direct concatenation. For high speed operation the 24-pole motor is operated as a single motor. In either case the primary of the 24-pole motor is connected to the line.

FIG. 3—ARRANGEMENT OF THE PRIMARY WINDING

This mill rolls rails from different materials and of various cross-sections and is also employed for rolling various sizes of bars. Although more than two speeds could be obtained with this cascade set, only two are employed, the motors being designed accordingly. Operation at the high or low speed is of course dependent on the material being rolled; however, both sets are always operated at the same number of poles. Fig. 4 shows diagrammatically the arrangement of the motors and mill.

FIG. 4—TYPICAL LAYOUT OF LIGHT RAIL AND BAR MILL WITH MULTI-SPEED INDUCTION MOTOR DRIVE
Two cascade sets are employed, giving two operating speeds for the mill.

Since changes in speed are not required at frequent intervals and never during operation, the secondaries of both motors of each set are so designed that a common external resistance and one set

of control apparatus will serve for both operating speeds. A general view of one of these cascade induction motor sets with the secondary resistance grids and the control apparatus is shown in Fig. 5.

MULTI-SPEED DRIVE OF PUMPS AND BLOWERS

The load on motors in steel operations is of necessity variable in character, while in the case of pump and blower drives the load is ordinarily practically constant, except when it is desired to operate the pump or blower at different outputs. In these applications the output is, of course, a function of the speed and accordingly

FIG. 5—ONE OF THE CASCADE SETS SHOWN IN THE DIAGRAM, FIG. 4
Both motors of each set are of the wound rotor type, the resistance grids and control apparatus shown in the foreground serving to start the set at either speed.

the problem involved is one of obtaining high efficiency of operation at different speeds. For applications of this kind induction motor drive is particularly adaptable. Such apparatus does not require high starting torque and, as the load at a given speed remain constant, that is, without the peak loads characteristic of roll mill service, the squirrel cage type of rotor may always be employed. These applications are becoming quite general, and in many cases involve large motor capacities.

An example of two-speed induction motor drive for pump service is to be found at the American Smelters Securities Company, Mexico. The motor of this set operates on a 550-volt, 25-cycle, three-phase circuit, the capacity being 50 hp when operating

as a four-pole motor, and 25 hp corresponding to eight poles. The primary winding consists of diamond coils connected as consecutive poles. For four-pole operation the winding is connected in parallel star, and for eight poles, in series delta, by the method illustrated in Fig. 3. A similar arrangement is shown in Fig. 6 in which a plunger pump is driven by means of a 150 hp, two-speed induction motor.

Another example of pump drive is to be found at the Quincy Market, Cold Storage and Warehouse, Boston, Mass. In this case a three-speed, 400-volt, 60-cycle, two-phase motor is used. The three speeds correspond to 8-pole, 10-pole and 16-pole operation, the capacities being 10 hp at highest speed, 7.5 hp at the medium
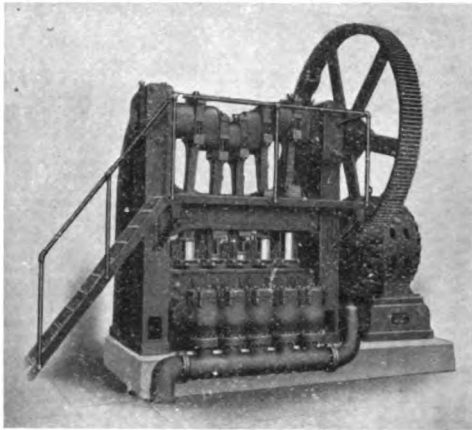
FIG. 6—QUINTUPLEX PLUNGER PUMP DRIVEN BY 150
HORSE-POWER, MULTI-SPEED INDUCTION MOTOR

speed and 5 hp at the lowest speed. The primary of this motor has two separate windings, one common to the 8-pole and 16-pole connections and the other for the 10-pole operation. When the motor is operated as an eight-pole machine the first of these windings is connected in parallel groups, and when run as a 16-pole machine, the groups are connected in series. The connections are made in a manner similar to that explained in connection with Fig. 3.

MULTI-SPEED DRIVE IN RAILWAY ELECTRIFICATIONS

An application of the multi-speed principle to electric railway operation, which has demonstrated the possibilities of the use of this method in the field of electric traction and which has excited a great deal of interest throughout the engineering world, is that of the Simplon Tunnel electrification. This tunnel serves as a connecting link between Italy and Switzerland, joining the towns of

Brig and Izelle, Switzerland, by a road* about 13.6 miles in length. The road is at present double track outside the tunnel and single track within; a second parallel tunnel is under construction, which, when equipped, will give a two-track right of way throughout the length of the line. The tunnel is about 12.4 miles in length. The locomotives are equipped with four-speed, 3 000-volt, 16-cycle, three-phase motors, the different speeds making them adaptable to both freight service and high speed passenger service. The primaries of the motors are provided with two separate windings, each of which may be connected in series—delta or parallel—star, in somewhat the same manner as that described in connection with Fig. 3. By this arrangement, speeds corresponding to 12 and 6 poles, respectively, may be obtained with one winding, and speeds corresponding to 16 and 8 poles, respectively, with the other winding. The normal ratings of the motors corresponding to operation with 6, 8, 12 and 16 poles, respectively, are 850 hp, 750 hp, 650 hp and 550 hp. The rotors are of the squirrel cage type. The three-phase transmission circuit involves the use of two overhead trolley wires, the bonded rails serving as the third conductor of the circuit.

These locomotives are a modification of an earlier type used in connection with this electrification. In the first locomotives used, the motors are of the wound secondary type, employing rheostatic control to obtain acceleration. The control provides for two running speeds by changing the number of poles in the primary windings (8 and 16 poles). These locomotives are still doing service on this system.

Two notable examples of railway electrification in which multi-speed, three-phase motors are employed are to be found on the Italian State Railways. On the Valtellina system, which is some 66 miles in length, the earlier locomotives were built in two sections and equipped with four motors, two primary and two secondary; i. e., in *two* sets to give two operating speeds, by direct concatenation and by operation of a single motor of each set by itself. The transmission system is operated at 20 000 volts, the voltage being supplied to the locomotives by stepping down through sub-stations to 3 000 volts, the operating voltage of the motors. The motors are of the wound-rotor type, fluid rheostats being employed to obtain gradations of speed for acceleration, etc. This system is

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*An elaborate description of this system is given in *Zeitschrift des Vereines deutscher Ingenieure* for 1909, p. 607; abstracted in the *Electrical Review and Western Electrician* of November 13th, 1909, p. 939.

operated at a frequency of 15 cycles. Two locomotives* of this type
were constructed and are still in service.

In the later type of locomotive† the control provides for *three*
operating speeds by means of two motors, one of eight poles and
the other of 12 poles. The lowest operating speed is obtained by
direct concatenation of the two motors, whereby an equivalent of
20 poles is obtained, giving a speed of approximately 16 miles per
hour. The second speed is obtained by connecting the 12-pole motor
singly to the line, a speed of approximately 26 miles per hour being
obtained. The highest operating speed is obtained by connecting
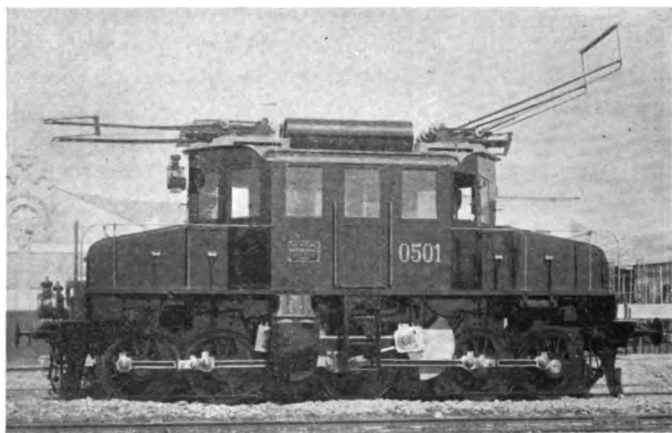
FIG. 7—ELECTRIC LOCOMOTIVE OF 2 000 HORSE-POWER CAPACITY

Equipped with two similar three-phase induction motors of 1 000
hp capacity. The two operating speeds are obtained by operating the
motors respectively in direct concatenation and in parallel. Power is
supplied directly to the motors through 3 000-volt, 15-cycle, three-
phase distribution, 20 000-volt transmission.

the eight-pole motor singly to the line. The motors are both of the
wound-rotor type, fluid rheostats being used, as in the earlier type of
locomotive. In the primary winding of the 12-pole motor, the coils
are arranged in three groups per phase. When the two motors are
connected in direct concatenation the respective groups of coils are
connected in three parallel groups per phase and the three phases
connected in delta. When the 12-pole motor is operated singly on

*Described in the *Street Railway Journal* for May 2nd, 1903, Vol. XXI.,
p. 663. A further description of this type of locomotive and a type of motor
car with similar motor equipment is given in a succeeding article in the issue
of May 30th, p. 788.

†Described in the *Street Railway Journal* for April 6th, 1907, Vol.
XXIX., p. 575.

the 3 000-volt line, the groups of each phase are connected in series and the phases are in turn connected in star. In this way the primary winding of the motor is better adapted to the voltages involved. The 8-pole motor is of 1 500 hp rated capacity and the 12-pole motor is of 1 200 hp capacity.

A second notable electrification in Italy, now under construction and shortly to be put in operation, is that of the Goivi line, a heavy grade mountain section of a trunk line connecting Genoa and Milan. The purpose of the electrification of this section of road, which is located near Genoa, is to handle the freight service with greater facility; the passenger service is to be maintained, as at present, by means of steam locomotives, over the older route, which is more circuitous and therefore involves more moderate grades. The locomotives used in this electrification are of 2 000 hp capacity. Two 3 000-volt, 15-cycle, three-phase motors are used on each machine. They are of the wound rotor type, using fluid rheostats. The two motors are operated in cascade connection to obtain the lower operating speed. For higher speed the motors are operated in parallel by direct connection to the line. One of these locomotives is shown in Fig. 7. A number of locomotives of this type are being built for use in some further foreign railway electrifications.

The first application of three-phase, multi-speed induction motors to electric railway operation in the United States is that of the electrification of the Cascade Tunnel on the main line of the Great Northern Railway, near Seattle. In this case the speed control is obtained entirely by the use of wound rotor type motors and external resistance.*

It may be stated, in general, that the methods given in the present and previous articles for obtaining multi-speed variation with induction motor drive are entirely practicable and may be considered as good engineering practice. In selecting a form of motor drive, especially in industrial applications, the question of cost and simplicity of manufacture always require due consideration. Sometimes these factors are not of so great importance as the fact that desired results can be obtained. Again, improved economy of operation often justifies greater initial cost of equipment. The fact should not be lost sight of, however, that because of their special construction, multi-speed induction motors cost more and require additional time to build.

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*These locomotives are referred to in an editorial in the JOURNAL for October, 1909, p. 580, and are described in a paper by Dr. Cary T. Hutchinson, Proc., A. I. E. E., November, 1909, p. 1 409.

TUNGSTEN ILLUMINATION

ARTHUR J. SWEET

T HE rapid growth and advancement of the science of illuminating engineering has called the very general attention of the educated public to the fact that there are certain scientific laws to which artificial lighting must conform, if low cost of operation is to be attained, and serious and disastrous eye-strain avoided. This is indeed the purpose of the new science,—at once the reason for its existence, and its justification,—to decrease the cost of artificial lighting, and to increase the efficiency and comfort of those who use artificial light by making the conditions of that use such as to avoid temporary or permanent injury to their eye-sight.

The introduction of the tungsten lamp makes the application of scientific laws to artificial lighting a virtual necessity. Not only does the tungsten lamp by its proper application make possible a great reduction in the cost of lighting; it also makes possible, by its improper use, a considerable increase in the extent and seriousness of eye troubles arising from artificial lighting. Yet the tungsten lamp, when properly used, is superior to all other illuminants of the present day in reducing eye strain to a minimum.

The lamp user is, therefore, confronted with the problem of how to obtain the economy of operation and the eye-comfort to which the science of illuminating engineering can guide him. He can seldom afford the time to qualify himself as a competent illuminating engineer. Neither does he ordinarily feel justified, unless he has in hand a large and important problem, in securing the services of an expert illuminating engineer.

Fortunately for the lamp user, the majority of illumination problems are but slight variations from a few standard problems. The common features of these many individual problems can be recognized, and the requirements to which they give rise can be fulfilled by proper design of lamp and reflector. For instance, illuminating engineers say that no intensely brilliant object, such as a glowing lamp-filament, shall be allowed within the normal field of vision. A reflector can be designed so as to conceal the filament itself, while distributing light from the filament, and the lower part of the lamp can be frosted, so as to conceal the filament for any normal position of the eye below the lamp. If now the user be supplied with this light unit (lamp and reflector), he need not be troubled with the necessity of conforming to or even of knowing the existence of

this particular law. The demands of the law have been met, once for all, in the design of the light unit.

In that large number of problems, therefore, which may be classed as standard or typical, the highly complex and technical features of illumination design can be taken care of and eliminated from the lamp user's concern by applying the highest grade of illuminating engineering ability to the design of the light unit (lamp and reflector). The application of these light units to any particular problem can then be taken care of by a few simple rules and tables. It is true that these rules and tables are simple only as regards the ease with which they may be understood and applied by any intelligent man; they must be drawn up with great care by a competent
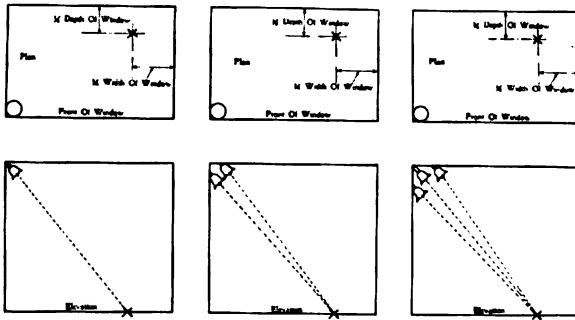
FIG. I　　　　　FIG. 2　　　　　FIG. 3

illuminating engineer, and must be based on a thorough and extended experience in illuminating design.

The essential facts which it is here sought to emphasize are these: That the lamp user, though most often he knows it not, is face to face with the necessity of carefully applying the principles of illuminating engineering to his lighting system, in order to obtain economy of operation and minimum eye-strain; that a careful study and analysis of the many separate illumination problems discloses certain factors and relations common to all these problems; that by designing a line of light units with reference to these common relations, the principles of illuminating engineering may be correctly applied by the lamp user to his particular problem by the simple procedure of determining from a table the correct light unit and the proper mounting height corresponding to the particular conditions of his problem; and that the illumination results will be nearly or quite as satisfactory as could be obtained by the direct, personal services of the best illuminating engineer.

Such a standard line of light units has been designed and is now on the market, using tungsten lamps and Holophane prismatic reflectors. This article, and the tables which accompany it, are presented as a hand-book on the use of this standard line of light units. The information here given is sufficient to enable any intelligent man to lay out a perfectly satisfactory illumination design for the ordinary residence, office of store. It is *not* sufficient to permit the layman to design the illumination for the banking room, the school room, the public library, or the like. These are the sort of problems in which the direct, personal services of a competent illuminating engineer should always be obtained.

The method and data here furnished are applicable to all the well-known makes of American tungsten lamps. This data is not
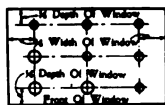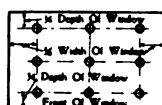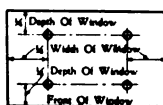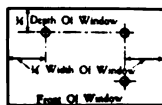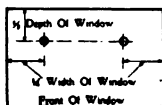
FIG. 4   FIG. 5   FIG. 6   FIG. 7
      FIG. 8   FIG. 9   FIG. 10

applicable at this writing, however, to foreign-made lamps, since none of these lamps have been designed with proper reference to a standard line of reflectors.

<center>GENERAL RULES</center>

1—Tungsten lamps should ordinarily be hung vertically pendant. When this is not practicable, the correct illumination design cannot be determined by the simple method here outlined. The problem of correct illumination then becomes one which should be referred to a competent and experienced illuminating engineer.

2—The right type and size of reflector and the right shade-holder must be used. The extensive, the intensive, and the focusing types of reflector are each designed to give satisfactory illumination results under certain definite conditions of number and position of outlets, and size and height of room. When any type is used under conditions for which it was not designed, unsatisfactory illumination is apt to result. The same reflector will give widely varying illumination results according as it is held in different positions relative to the lamp. Therefore, to obtain correct illumination results,

the proper shade-holder must be used. The reflector which is designed for one size of lamp will give different and usually very unsatisfactory illumination results when used with any other size of lamp.

3—The different types of reflector are not designed to give different illumination results. They are designed to give the same result, each type being suitable to a different condition of position of outlets and size of room.

4—The lamps should be bowl frosted. Clear lamps will give slightly less satisfactory results, and lamps frosted all over will give results considerably less satisfactory.

TABLE I

TYPE OF SERVICE	WATTS PER SQUARE FOOT
Drafting room	1.00 to 1.25
Factory, general illumination only, where additional special illumination of each machine or bench is provided	0.40 to 0.60
Factory, complete illumination	1.00 to 1.25
Hotel, halls	0.20 to 0.30
Hotel, guests' rooms	0.50 to 0.70
Hotel, parlors	0.40 to 0.50
Office, waiting or consultation room	0.40 to 0.50
Office, private office or board room (no individual desk lighting)	0.60 to 0.75
Office, general office or bookkeeping (no individual desk lighting)	0.90 to 1.20
Office, private or general (general illumination only where individual desk lighting will be used in addition)	0.30 to 0.45
Residence, halls	0.20 to 0.30
Residence, sleeping rooms	0.30 to 0.45
Residence, living rooms	0.50 to 0.75
Store, book, furniture	0.75 to 1.00
Store, light-colored fabrics, china, drug, jewelry, shoe, hardware, etc	0.90 to 1.20
Store, dark-colored fabrics, clothing	1.20 to 1.50
Train Sheds	0.30 to 0.40
Warehouse	0.30 to 0.50

NOTE.—Use larger watt per square foot values in above table when room has dark walls. Use smaller watt per square foot values when room has light colored walls.

The values given in the above table hold true only for the types of lamps and reflectors as given in Table III.

5—Reflectors must be kept clean, as all reflectors lose tremendously in efficiency when allowed to become dirty.

6—Use satin-finished reflectors only where it is certain that reflectors will be kept absolutely clean. Satin-finished reflectors give a softer and a more pleasing light than clear reflectors, but, on the other hand, their efficiency is more seriously affected by dirt.

7—Several small lamps at each outlet are much preferable to one large lamp. One large lamp at each outlet casts a shadow whose edges are sharply defined. Such shadows are objectionable, even

when not very deep (i. e., dark). Several lamps at each outlet give a shadow effect, but such shadow effect fades imperceptibly into the shadowless field, there being no sharp edges. This shadow effect, so far from being undesirable, actually improves the efficiency of illumination when the central portion of the shadow is not too deep. This is due to the fact that such shaded portions, by their contrast, relieve eye-strain. Three or four lamps at each outlet is usually the most desirable number.

TABLE II

One outlet in center of room				One line of outlets down center of long room			Four or more outlets arranged on base of square or rectangle		
Mean dimension of room (Note 1)	Mounting height and reflector to be used			Width of room	Separation of Units (Note 2)	Mounting height and reflector to be used (Note 2)	Mean separation of outlets (Note 3)	Mounting height and reflector to be used	
	Bath room, vestibule or the like	Residence or hotel room	Office, store, or assembly room					Room with low or moderate height ceiling	Room with high ceiling
3 ft.	3 ft. Focusing	.....	.....	Less than 9 ft.	7 ft. to 9 ft.	6½ ft. Extensive	6 ft.	7½ ft. Intensive	12 ft. Focusing
4 ft.	4 ft. Focusing	...	.....	9 ft.	8 ft. to 10 ft.	4½ ft. Extensive	7 ft.	8½ ft. Intensive	11½ ft. Focusing
7 ft.	7½ ft. Intensive	....	.	10 ft.	9 ft. to 11 ft.	7 ft. Extensive	8 ft.	9½ ft. Intensive	15 ft. Focusing
8 ft.	8½ ft. Intensive	....	..	11 ft.	10 ft. to 12 ft.	7½ ft. Extensive	9 ft.	10 ft. Intensive	16½ ft. Focusing
10 ft.	9½ ft. Intensive	...	.....	12 ft.	11 ft. to 13 ft.	8 ft. Extensive	10 ft.	11 ft. Intensive	18 ft. Focusing
12 ft.	11 ft. Intensive	....	..	13 ft.	11½ ft. to 14½ ft.	8 ft. Extensive	11 ft.	11½ ft. Intensive	18½ ft. Focusing
9 ft. to 11 ft.	....	6½ ft. Intensive	6½ ft. Extensive	14 ft.	12½ ft. to 15½ ft.	8½ ft. Extensive	12 ft.	12½ ft. Intensive	21 ft. Focusing
12 ft.	...	6½ ft. Extensive	7 ft. Extensive	15 ft.	13½ ft. to 16½ ft.	9 ft. Extensive	13 ft.	13½ ft. Intensive	22½ ft. Focusing
13 ft.	...	7 ft. Extensive	7½ ft. Extensive	16 ft.	14½ ft. to 17½ ft.	9½ ft. Extensive	14 ft.	14 ft. Intensive	24 ft. Focusing
14 ft.	...	7 ft. Extensive	8 ft. Extensive	17 ft.	15½ ft. to 18½ ft.	10 ft. Extensive	15 ft.	15 ft. Intensive	25½ ft. Focusing
15 ft.	...	7½ ft. Extensive	8½ ft. Extensive	18 ft.	16 ft. to 20 ft.	10 ft. Extensive	16 ft.	15½ ft. Intensive	27 ft. Focusing
16 ft.	.	8 ft. Extensive	9 ft. Extensive	20 ft.	18 ft. to 22 ft.	11 ft. Extensive	18 ft.	17½ ft. Intensive	30 ft. Focusing
18 ft.	.....	8½ ft. Extensive	9½ ft. Extensive	22 ft.	20 ft. to 24 ft.	12 ft. Extensive	20 ft.	19 ft. Intensive	33 ft. Focusing
20 ft.	..	9 ft. Extensive	10½ ft. Extensive	24 ft.	21½ ft. to 26½ ft.	12½ ft. Extensive	24 ft.	22 ft. Intensive	39 ft. Focusing
24 ft.	...	10½ ft. Extensive	12 ft. Extensive	27 ft.	24½ ft. to 29½ ft.	14 ft. Extensive	30 ft.	27 ft. Intensive	48 ft. Focusing
30 ft.	...	12½ ft. Extensive	14½ ft. Extensive	30 ft.	27 ft. to 33 ft.	15 ft. Extensive	40 ft.	35 ft. Intensive	63 ft. Focusing

NOTE 1—Half the sum of length of room plus width of room.

NOTE 2—This spacing of light units must be obtained. If present spacing of outlets does not agree with required spacing, the light circuit may be run in conduit or molding.

NOTE 3—Half the sum of distance between adjacent outlets along one side of rectangle plus the distance between adjacent outlets along adjacent side of rectangle.

PROCEDURE

In laying out any given illumination design, there are three things to be determined:

a—The number of lamps at each outlet, and the size of lamp to be used.

b—The type and size of reflector.

c—The mounting height of lamp and reflector. This mounting height is measured from the floor to the center of the lamp filament.

(a) Number and size of lamps: — From Table I obtain the watts per square foot required by the particular kind of interior which it is desired to illuminate. Multiply the watts per square foot by the number of square feet of floor area to determine the total watts

required for the room. Divide the total watts by the number of outlets to obtain the required watts at each outlet. Keeping in mind General Rule 7, choose the number and size of lamps at each outlet, so that the total wattage represented by the number of lamps and size chosen is approximately the amount desired per outlet. The lamps chosen should, of course, be of a standard type.

(b) Type and size of reflector:—From Table II obtain type of reflector, whether extensive, intensive, or focusing. From Table III obtain size of reflector as indicated by designating number, the size of reflector being chosen to accord with the size of lamp determined upon under (a). Also obtain proper shade-holder from Table III.

ⵑ TABLE III

Lines and Regular Types of Tungsten Lamp		HOLOPHANE REFLECTORS			
Line	Wattage Type	Extensive Catalogue No	Intensive Catalogue No	Focusing Catalogue No.	Type of Holder
220 volt line	150 watt	106290 (E-13)	106190 (I-13)	106390 (F-13)	Form A
	110 watt	106285 (E-11)	106185 (I-11)	106385 (F-11)	Form A
	70 watt	106290 (E- 9)	106190 (I- ⁀)	106390 (F- 9)	Form H
	45 watt	106250 (E- 7)	106150 (I- 7)	106350 (F- 7)	Form H
110 volt line	250 watt	106290 (E-13)	106190 (I-13)	106390 (F-13)	Form A
	150 watt	106285 (E-11)	106185 (I-11)	106385 (F-11)	Form A
	100 watt	106290 (E- 9)	106180 (I- 9)	106380 (F- 9)	Form H
	60 watt	106250 (E- 7)	106150 (I- 7)	106350 (F- 7)	Form H
	40 watt	106230 (E- 5)	106180 (I- 5)	106330 (F- 5)	Form H
	25 watt	106225 (E- 3)	106125 (I- 3)	106325 (F- 3)	Form O
27 volt line	40 watt	106225 (E- 3)	106125 (I- 3)	106325 (F- 3)	Form O
	25 watt	106225 (E- 3)	106125 (I- 3)	106325 (F- 3)	Form O
	20 watt	106225 (E- 3)	106125 (I- 3)	106325 (F- 3)	Form O
	15 watt	106225 (E- 3)	106125 (I- 3)	106325 (F- 3)	Form O
	10 watt	106225 (E- 3)	106125 (I- 3)	106325 (F- 3)	Form O

(c) Mounting height:—From Table II determine the mounting height.

SPECIAL PROBLEM : LONG, NARROW STORE

The illumination of a long, narrow store, having on each side counters running lengthwise of the store, with two lines of outlets, one above each counter, is an illumination problem which has not been covered by the preceding paragraphs but which occurs frequently enough to deserve notice. In this case it is necessary to insist on a certain definite spacing of light units, and the lighting circuit should be run in conduit or molding to the proper connections if the spacing of the outlets does not closely agree with this required spacing of the light units.

With the spacing of light units given below the following illumination design will be found very satisfactory.

Lamp—40 watt, bowl-frosted; reflector—106330 clear; holder --Form H; mounting height above top of counter—six feet to six feet four inches; distance apart of adjacent light units—six feet to six feet six inches.

Light units should be hung directly over center of the counters, or, better yet, six to 12 inches nearer to side wall than center of counter.

DESK LIGHTING

Desk lighting is generally to be avoided, particularly in large offices where a number of desks are located. In the case of practically all large offices and in most private offices it will be found much the better plan to provide for a general illumination sufficiently bright to make desk lighting unnecessary. Desk lighting involves of necessity a somewhat greater strain on the eyes than correctly designed general

TABLE IV—DESK LIGHTING

With Single Light Unit					With Two Light Units		
Approximate Diameter of Circle Illuminated	Mounting Height Above Top of Desk	Lamp	Reflector	Holder	Approximate Dimensions of Oval Area Illuminated	Mounting Height Above Top of Desk	Distance Apart of Light Units
1'-8"	3'-4"	25 watt Bowl-Frosted 1	106325 Satin-Finish	Form O	2'-0" x 3'-0"	4'-0"	3'-4"
2'-4"	4'-2"	40 watt Bowl-Frosted 2	106330 Satin-Finish	Form H	2'-6" x 6'-2"	5'-0"	3'-8"
2'-4"	5'-2"	60 watt Bowl-Frosted 3	106350 Satin-Finish	Form H	3'-2" x 8'-0"	6'-4"	4'-10"
3'-4"	6'-5"	100 watt Bowl-Frosted 4	106380 Satin-Finish	Form H	4'-2" x 10'-6"	8'-4"	6'-4"
2'-2"	4'-4"	25 watt Bowl-Frosted 1	106325 Clear	Form O	2'-8" x 6'-8"	5'-4"	4'-0"
2'-10"	5'-6"	40 watt Bowl-Frosted 2	106330 Clear	Form H	3'-2" x 8'-0"	6'-4"	4'-10"
3'-4"	6'-6"	60 watt Bowl-Frosted 3	106350 Clear	Form H	3'-10" x 9'-6"	7'-8"	5'-8"
4'-2"	8'-4"	100 watt Bowl-Frosted 4	106380 Clear	Form H	4'-10" x 12'-0"	9'-6"	7'-2"

1. Also 20 watt and 25 watt, 27 volt.
2. Also 45 watt, 220 volt, but used with reflector 106350 and Form H holder.
3. Also 70 watt, 220 volt, but used with reflector 106380 and Form H holder.
4. Also 110 watt, 220 volt, but used with reflector 106385 and Form A holder.

illumination, even when the desk lighting has been laid out as closely as possible in accord with the principles of illuminating engineering. And it is the almost universal experience with installations of desk lighting that the illuminating engineer has scarcely turned his back on the problem before the individual desk users start in to modify their installation, so as to make it accord with their own prejudices, with a result that the conditions which make for eyestrain and permanent injury to the eye are increased to a dangerous, though seldom recognized, degree.

Desk lighting should generally be restricted to cases where one cr two desks are located in an office chiefly used for other purposes which permit of a comparatively low degree of illumination. In such cases, the following general rules and table will be found of value.

1—Do not locate the desk light close to the work. The light

unit should be located well above the desk, and about 12 inches to 18 inches in towards the center from the front of the desk.

2—Two smaller desk lights are preferable to one larger one. They should be located at such distance apart as given in Table IV, and at an equal distance to the right and left of the desk user.

3—Satin - finish reflectors are preferable to clear reflectors, but they must be kept absolutely clean.

Table IV gives full data for satisfactory desk lighting. For an ordinary desk, decide whether one or two light units will be used. If a long desk, as a ledgerman's desk or the like, several units must, of course, be used, these lights being located about 12 to 18 inches in from the front of the desk and at the distance apart specified in the table. After the number of light units has been decided upon, obtain from Table IV the desired data on lamp, reflector, mounting height above desk, etc., to correspond with the area which it is desired to illuminate.

TABLE V—SHOW-WINDOW LIGHTING

Area of Window Floor in Square Feet	Light Units to be Located in Upper Front Corner				Light Units to be Located on Ceiling			
	Lamp and No. of Lamps Required	Reflector	Holder	Arrangement	Lamp and No of Lamps Required	Reflector	Holder	Arrangement
20	1-100 watt Bowl-Frosted	106180 Clear	Form R	See Fig. 1	2-25 watt Bowl-Frosted	106325 Satin Finish	Form O	See Fig. 4
25	2-60 watt Bowl-Frosted	106350 Clear	Form H	See Fig. 2	1-25 watt Bowl-Frosted	106325 Satin Finish	Form O	See Fig. 5
30	1-100 watt Bowl-Frosted 1-60 watt* Bowl-Frosted	106180 Clear 106350 Clear	Form H Form H	See Fig. 2	1-25 watt Bowl-Frosted	106325 Satin Finish	Form O	See Fig. 5
35	2-100 watt Bowl-Frosted	106180 Clear	Form H	See Fig. 2	4-25 watt Bowl-Frosted	106325 Satin Finish	Form O	See Fig. 6
40	1-250 watt Bowl-Frosted	106190 Clear	Form A	See Fig. 1	4-25 watt Bowl-Frosted	106325 Satin Finish	Form O	See Fig. 6
60	1-250 watt Bowl-Frosted 1-150 watt* Bowl-Frosted	106190 Clear 106180 Clear	Form A Form H	See Fig. 2	4-40 watt Bowl-Frosted	106110 Satin Finish	Form H	See Fig. 6
90	2-150 watt Bowl-Frosted	106190 Clear	Form A	See Fig. 2	9-25 watt Bowl-Frosted	106125 Satin Finish	Form O	See Fig. 7
125	3-250 watt Bowl-Frosted	106190 Clear	Form A	See Fig. 3	3-40 watt Bowl-Frosted 6-25 watt Bowl-Frosted	106110 Sat. Fin. 106125 Sat. Fin.	Form H Form O	See Fig. 8
160	3-250 watt Bowl-Frosted	106190 Clear	Form A	See Fig. 3	9-40 watt Bowl-Frosted	106110 Satin Finish	Form H	See Fig. 7
200	3-250 watt Bowl-Frosted	106190 Clear	Form A	See Fig. 3	1-250 watt Bowl-Frosted 3-100 watt Bowl-Frosted 5-60 watt Bowl-Frosted	106390 Sat. Fin. 106180 Sat. Fin. 106180 Sat. Fin.	Form A Form H Form H	See Fig. 9
250	3-250 watt Bowl-Frosted	106390 Clear	Form A	See Fig. 3	2-250 watt Bowl-Frosted 7-100 watt Bowl-Frosted	106390 Sat. Fin. 106180 Sat. Fin.	Form A Form H	See Fig. 10

*Larger lamp is located directly above the smaller lamp.

correspond with the area which it is desired to illuminate.

The lighting of a billiard table, a library table, or the like, should be treated as a case of desk lighting, two light units *always* being used. Obtain from Table IV the desired data on lamp, reflector, mounting height above table, etc., to correspond with the area which it is desired to illuminate.

Successful show-window lighting is characterized by two features. First, the window should be so brilliantly lighted as to attract the attention of the passer-by to the goods there displayed. And second, the goods themselves should be so attractively illuminated that they show up at their best when the closer scrutiny of the passer-by has been drawn to them. To insure brilliant lighting of a window is chiefly a question of using a sufficient number of correctly designed light units. To illuminate the goods so that they will show up to the maximum advantage is a much more difficult problem.

One frequent defect of window lighting is flatness, or lack of perspective due to very uniform illumination and the elimination of shadows. Sharply defined shadows, providing they are not too deep, make the goods stand out in perspective and add greatly to the attractiveness of the illumination. The desired shadow effect is obtained by massing a considerable proportion of the light units used in either the right or left upper front corner of the window. In order to prevent the shadow effect from being too deep, the remaining light units are properly spaced over the ceiling.

Lack of sufficient diffusion is another defect often seen. This defect can be avoided by the use of satin-finish reflectors for the ceiling light units. It must be remembered that these reflectors should be kept absolutely clean.

A correct and very satisfactory design of window lighting may be obtained from Table V. Referring to this table, find the proper light units to be used in the upper front corner of the window, and also the proper light units to be used on the ceiling, these being chosen to correspond with the proper square-foot area value which most nearly represents the actual floor area of the window space to be lighted. Install these light units in the window in accordance with the arrangement specified in Table V. The ceiling lights should be mounted directly on the ceiling, not suspended on a drop from it.

An illumination design, obtained as above, for show-window lighting is very satisfactory for the average case of this class of lighting. It will not, however, give good results for windows having unusually high or unusually low ceilings. The method here given should never be used when the ceiling height of the window is less than half the width of the window nor when the ceiling height is greater than twice the width of the window.

LARGE SELF-COOLING TRANSFORMERS

W. M. McCONAHEY

N EW conditions, brought about by the increasing use of electric power and the rapidly widening field of its application, necessitate modifications in the design of old apparatus and the development of new types. In transformer practice new requirements have arisen from time to time resulting in improved or new designs to care for the new conditions. The first transformers built were of the air-cooled type. This type of transformer could not be built economically except for small sizes and moderate voltages. When the demand arose for transformers of larger size and higher voltage, the oil-insulated, self-cooling type was developed. This type met all requirements for a time, but it was not long until it became necessary to supply transformers of such size that they could not be made self-cooling. This necessitated the adoption of some artificial method of cooling and hence the oil-insulated, water-cooled, and later, the air-blast, types were developed. The application of air-blast transformers is limited because they cannot be built for voltages higher than about 35 000 volts, and it is generally cheaper and more convenient to cool by water than by air blast. The oil-insulated, water-cooled type can be built for practically any size or voltage required and has become almost a universal standard for large, high voltage transformers. There are, however, many places where self-cooling transformers of larger sizes than have heretofore been built would fulfil requirements much better than any other type.

The main advantage of the self-cooling transformer lies in the fact that no auxiliary cooling device of any kind is used. All that is necessary is to locate the transformer in such a way that fresh, cool air can circulate freely about it and carry away the heat. In many cases it would be a decided advantage to have large self-cooling rather than water-cooled transformers, and in some cases the use of the latter is out of the question. Where the cost of water for cooling purposes is such as to represent the interest on a considerable capital investment, it is better to use self-cooling transformers if they can be built in large enough sizes. The same is true if they are located in a sub-station in a climate where the temperature may fall very low in winter. In such a location special care must be taken to prevent the water supply of water-cooled transformers from freezing and, if it should be found necessary to take

a transformer out of service, all water must be removed from the cooling coils or there will be great danger of its freezing and bursting the coils. In any case, auxiliary devices require increased attention.

It often happens that sub-stations are located in out-of-the-way places where water-cooled transformers cannot be used because of

FIG. I—100 000-VOLT, I 000 KW SELF-COOLED TRANSFORMER
With cooling tubes through which the oil circulates.

lack of water or where it is particularly desirable to have apparatus requiring as little attention as possible.

Large transformers are now being installed quite frequently out of doors and in such cases the self-cooling type is obviously the only satisfactory one to use on account of the attention required by artificially cooled transformers. The maximum size for which a transformer can be built self-cooling is limited by the amount of heat radiating capacity for which the case can be designed. Standard cases with corrugated sides are used with transformers of capacities up to about 600 or 750 k.v.a., but beyond this size the weight and size of case become so great that some method, other

than mere increase in size, must be resorted to in order to get the necessary radiating surface. The above considerations show clearly the desirability of and the demand for self-cooling transformers of large size.

The electrical engineers of the Westinghouse Company have been working on this problem for some time and have developed a type of design that is simple in construction and can be built for much larger sizes than has ever been attempted for self-cooling transformers. The transformer itself does not differ from the standard water-cooled type but the design of the case is entirely new. It is
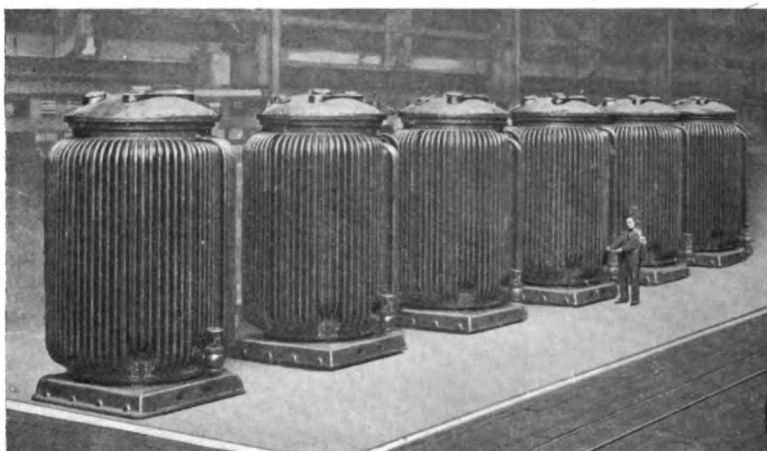
FIG. 2—GROUP OF SIX TRANSFORMER CASES WITH SPECIAL CIRCULATING TUBES
For use with 100 000-volt, 1 000 kw transformers.

a boiler iron case having a large number of tubes arranged vertically around the outside and entering the case near the top and bottom. The tubes are given a 90 degree bend around a large radius at the ends and are fitted in place in the same manner as boiler tubes and carefully welded. Cases built in this manner are simple in design, exceedingly strong and practically free from any chance of ever springing a leak. The tubes are widely separated from one another so as to allow the air to circulate among them in the freest possible manner. This makes the radiating surface very efficient and much more effective, area for area, than the surface of ordinary corrugated case self-cooling transformers.

Twelve 1 000 k.v.a., 100 000 volt transformers of this type have already been built for the Southern Power Company. Three of these are for outdoor service and three for indoor.

THE STEAM CONDENSING PLANT

J. A. McLAY

Engineer, British Westinghouse Electric & Mfg. Company

UNTIL a few years ago, the steam condensing plant did not receive much attention as, with an engine of the reciprocating type, there is practically no advantage to be gained in working with a vacuum of more than 26 inches. This is owing to the fact that at higher vacua the volume of the steam increases rapidly, so that to utilize it efficiently, engine cylinders would have to be made of enormous size. With the introduction of the steam turbine, however, this limiting factor was at once removed, and engineers have devoted their energies to improving the efficiency of the condenser with a view to getting the best possible results out of the whole equipment. Unfortunately, most of them devoted their attention to the condenser only, whereas the weak point was the air pump. All sorts of arrangements of tubes and baffle plates, tubes inside of tubes, corrugated tubes, drainage chambers, tubes kept dry and tubes kept wet, etc., were fitted to surface condensers: and in jet condensers, baffle plates and trays and counter-current effects, etc., were applied. Of course, for all of these improvements, great results were claimed, but they do not seem to have been fulfilled.

At first sight it would appear that if sufficient water were introduced into a condenser to take the latent heat out of the steam at the temperature corresponding to the desired vacuum, the desired results would be produced. It must be borne in mind, however, that there is always more or less air in water and, as air is one of the poorest heat conductors, unless means are taken to remove it from the condenser, it will soon destroy the heat transmitting efficiency of the condenser. Beside the difficulty due to air dissolved in the water, there is always more or less leakage into a vacuum system through pipe joints, valve spindles, glands, and even through the metal in places where it is porous. It is therefore a very important matter to prevent leakage of air into the system, and also to have efficient pumps for removing the air.

So long as there was no use for a higher vacuum than 26 inches, the air pump scarcely entered into the question, as it is comparatively easy to deal with air at 26-inch vacuum, owing to the fact that it is comparatively dense; however, with the introduction

of the steam turbine and the need for higher vacua, the existing types of air pumps developed unknown defects. Various attempts were made to produce a pump which would overcome the difficulties, but it was not until M. Maurice Leblanc took up the matter that a satisfactory machine was produced.

A Leblanc rotary dry air pump is shown in section in Fig. 1. It consists primarily of a reversed turbine wheel in conjunction with an ejector. Water is led into the central chamber and passes
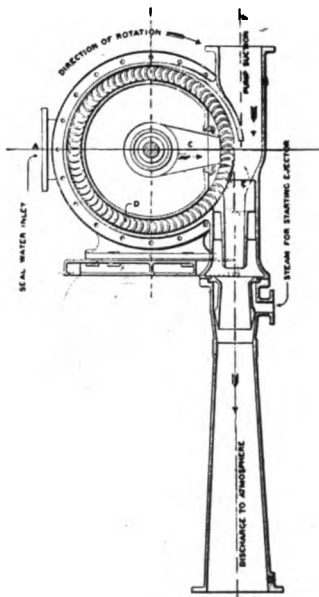
through a port, where it is caught up by the blades of the turbine wheel, which is rotated at high speed. The air and incondensable gases coming from the condenser are introduced into the pump at one end of the ejector, pass down into the pump, and are caught up by the sheets of water ejected from the blades of the turbine wheel. These sheets of water have a high velocity and fill up the space in the discharge branch, thus forming little water pistons, which carry the air, etc., from the condenser, against atmospheric pressure, without slip or leakage. Thus the pump apparatus operates as a rotary, valveless, water-sealed pump without piston, valves or clearance. The sealing water is always taken from the coldest supply available. It follows, therefore, that

there can be no trouble or loss of efficiency due to de-aeration or re-evaporation of the water, and as the volume displaced depends upon the number of water pistons, the efficiency is constant, no matter what vacuum the pump is drawing from, so long as the speed is kept constant and the same quantity of sealing water put through the pump.

Each sheet of water is ejected from the turbine wheel blades in such a manner that there is no shock when it meets the sides of the discharge cone, and as the velocity across the face of the blades is low, there is no wear on any of the parts. The heat generated during compression is absorbed by the sealing water, but as the mass of the water is very much greater than that of the air, the

temperature of the water is not increased appreciably. The clearance spaces between the moving blades and the stationary parts are made amply large, as they have no effect on the working of the pump. There is accordingly no risk of damage to the blades through wear of the bearings.

In a reciprocating type of pump there is a continual wear on the buckets, rods, valves, etc., so that apart from other causes, the efficiency gradually decreases. In addition there are connecting rods, cross-heads, gearing, etc., all requiring attention and overhauling, so that repairs, renewals, and maintenace form a very heavy charge. The only parts on a Leblanc type of pump, however, on which wear may take place, are the bearings, and, as these are all of the ring lubricated type with renewable gun metal bearings, the expense and time required to renew them are both small.

The usual method of testing an air pump is to insert a nozzle of known bore into the suction branch and to observe the vacuum maintained by the pump and the barometric pressure at the time of the test. The quantity of air passing through the nozzle can then be very easily calculated. This gives a true measure of the actual capacity of the Leblanc pump under working conditions because it does not matter whether the air dealt with is wet or dry. If at any time after installation a question should arise as to the working of the pump, it is only necessary to break one pipe joint—the air suction pipe—to make an accurate test, and determine in

FIG. 2—DETAIL SECTION OF LEBLANC EJECTOR CONDENSER

a few minutes whether or not the pump is satisfactory.

With a reciprocating pump, however, it is impossible to reproduce exactly the working conditions obtaining when it is drawing from a condenser, and the makers are consequently unable to say—in the event of trouble arising—whether or not the pumps are in order. The same method is used to arrive at the displacement of

the reciprocating pump, but in order to make this test it is necessary to introduce water into the pump to seal the bucket, gland and valves in the "Edwards" type. The water introduced, however, is cold—say, at a temperature of 60 degrees F., the corresponding vacuum being 29.5 inches. This, of course, gives an enormously exaggerated displacement. This applies as well to the dry air pump unless the counter current principle is actually realized in the condenser proper.

As was natural, Parsons was among the first to recognize the limitations of the existing reciprocating pumps, and therefore set about to devise some means of aiding in attaining a high vacuum with this type of pump. The outcome of his investigations was the augmentor* which is, in effect, a first stage pump which takes the rarified air from the condenser, compresses it slightly, and delivers it to the air pump. The augmentor works satisfactorily, but it is not economical, due to its large steam consumption; moreover, it adds another complication to an already complicated plant. When it is remembered that water contains a good deal of air in solution —about three or four percent by bulk—it is obvious that with the Parsons arrangement the air has every opportunity to become separated from the water, so that in addition to the air coming into the condenser with the steam and from leakage, the air pump has to deal with the air liberated from the cooling water. Not only this, but the freeing of this air prevents
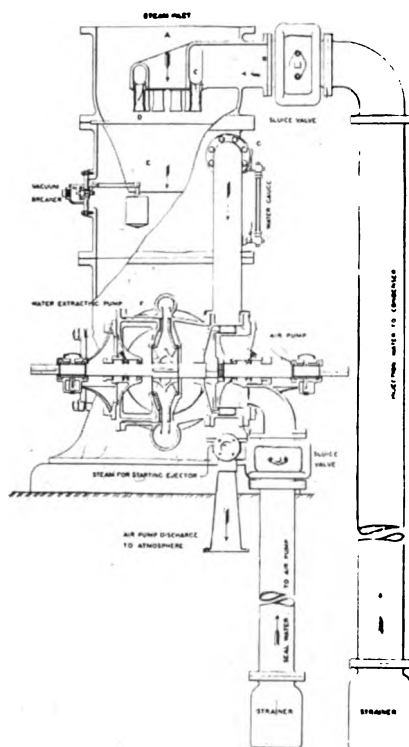
FIG. 3—DETAIL SECTION OF LEBLANC JET CONDENSER AND PUMPS

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*See the JOURNAL for September, 1909, p. 561, Fig. 15.

the intimate mixing of water and steam necessary to produce the best results.

The Leblanc condenser while ordinarily built as a low level type can also be arranged as a barometric jet. Independent Leblanc air pumps are made which can be used for surface condensers where this type is necessary on acount of feed-water conditions. The Leblanc multiple jet type of condensing plant is of the parallel flow type, that is, the steam to be condensed and the cooling water enter the condenser at the top and travel down together, as shown in Fig. 3. The water enters the distributing ring with considerable velocity; it passes through the nozzles which serve to spray it, and catches up the steam. The steam and the water then pass through the internal cone, where the steam is condensed and the air and non-condensable gases receive a first compression. The condensed steam and injection water fall to the bottom of the condenser and are removed by means of the water extracting pump, while the air and other gases rise around the outside of the cone and are drawn off by the air pump.

Obviously, in this type of condenser the air in solution in the water has no time to separate itself. The air pump, therefore, is not required to deal with it; indeed, some of the air brought in with the steam is probably entrapped and carried out by the water. Exceptionally good results are accordingly obtained. The condenser can generally be placed immediately below the turbine exhaust. All exhaust piping is thus avoided and the full benefit of the vacuum is secured at the turbine blades. With the Leblanc air pump, it is impossible for the water to rise in the condenser in the event of the pumps stopping, because there are no valves, etc., to impede the air which rushes in and breaks the vacuum and thus cuts off the supply of water to the condenser.

When it is stated that the Leblanc arrangement of water pistons can remove nine cubic feet of air per cubic foot of water as against one cubic foot of air per cubic foot of water in the ordinary ejector condenser, the greater efficiency of the Leblanc simple jet condenser, both in water consumption and in capacity for dealing with air leakage, will at once be seen.

NOTES ON THE COST OF OPERATING MACHINE TOOLS

A. G. POPCKE

I N addition to the wages of the machinist, there are other hourly operating expenses which must be charged against each tool in a machine shop. These will be referred to in this article as machine-hour rates. They include a proportional share of the *general charges* and also specific charges relating to each specific tool. The conditions are somewhat similar to those encountered in central stations. Before competition was very great, it was considered sufficient to figure the cost of generating power from the amount of coal and water consumed, and the wages of the power house attendants. Many industrial plants of considerable size that generate their own power still use this method. Most central station managers, however, have found it necessary, as the demand for power increased and the business became more complicated, to figure more closely and to analyze more thoroughly, *all* their expenses, among which are interest and depreciation on the cost of all buildings and equipment, salaries of officials, engineering staff, clerks, miscellaneous office expenses and advertising charges.

In a machine shop these charges may be considered under three general heads—fixed charges, variable charges and salaries. They can be determined for a given shop at intervals of a month or more and then divided among the several machines. The best method of making this divsion depends on so many local conditions that no general rules can be given. If all the tools are doing work of the same general class and are in use approximately the same proportion of the total time, a part of the total general charge can be set off against each tool in proportion to the floor space occupied by both the tool and the material on which it works. The general charge against each tool continues whether the tool is operating or idle, and the method of dividing the general charges must always take this fact into consideration.

Fixed charges include interest, insurance, and taxes on the investment in buildings and auxiliary equipment, such as heating and ventilating systems, fire appliances, benches, cranes, etc. If a shop is rented, the rental must include the foregoing charges and an additional sum for profit to the owner.

Variable charges include repairs on buildings and equipment to maintain the efficiency, losses due to breakage, defective material, defective design, workmanship, etc.

Salaries include cost of management, superintendence, engineering and designing, clerical work, care of plant, miscellaneous labor, etc.

In addition to the foregoing general charges, the cost of operating a tool is affected by the following *specific charges* which can be determined for each tool:

Interest on the cost of the tool and its auxiliaries.

Depreciation of the tool and its auxiliaries.

Cost of power consumed by the tool.

The interest on the cost of the tool is fairly taken at six percent. A reasonable method of making allowance for depreciation, in most cases, is to allow ten percent of a reducing balance; that is, ten percent of the first cost is charged off the first year, then ten percent of the remaining cost the second year, and ten percent of that remainder the third year, etc. This method is based on the fact that the apparatus actually decreases in value year by year. Allowance for depreciation in any given year can be made by the aid of Fig. 1.
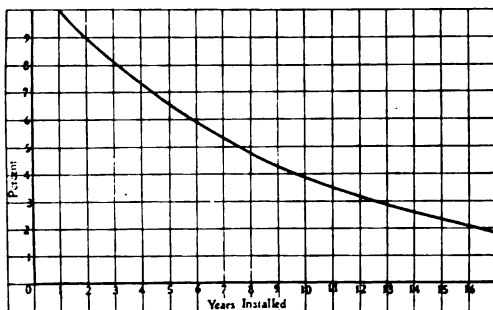
FIG. 1—DEPRECIATION AT 10 PERCENT REDUCING BALANCE

This curve gives the percent of the first cost corresponding each year to ten percent on the reduced balance. For example, the curve shows that the depreciation on a tool that has been in service five years will be 6.6 percent of the original cost. If this cost was $3 800 the allowance for depreciation during the sixth year, according to the ten percent reducing balance method, is $3 800×0.066=$250.80. Since this amount is ten percent of the reduced cost the value of the tool at the end of the fifth year is $2 508.

Tools for special work which will be discontinued after a comparatively limited period depreciate in value much more rapidly than is indicated by the foregoing method; a special allowance, generally known as utility depreciation, should be made for such tools.

The cost of power for each tool can be obtained by ascertaining the power demand in kilowatts per hour and multiplying

·this number of power units by the cost per unit and the number of working hours. If power is generated under the shop management, its cost must be determined from the station records; if purchased, the contract price must be used. If the machines are equipped with individual motors records for each class of work may easily be obtained by the use of graphic recording meters. These records will show what the standard conditions should be and what they actually are. · Check records may be taken frequently to see that all machines are working at the desired efficiency.

Each machine may be considered as a manufacturing center and the general charge against it as rental. Each center receives its material from another, performs some work on it and passes it on

TABLE 1.—LIST OF GENERAL AND SPECIFIC CHARGES AGAINST
MACHINE TOOLS

General Charges Against Total Shop	Charges Against Each Machine Tool
FIXED CHARGES Interest and depreciation on buildings and accessories	Proportional share of total fixed charge

VARIABLE CHARGES
  Repairs and Renewals
  General Operating Expenses
	Proportional share of total variable charge

SALARIES
  Supervision
  Engineering
  Clerical
	Proportional share of total salaries

	Interest on cost of tool Depreciation on cost of tool Cost of power for tool

with an added value to the next center. This added value, less the general and specific charges, is the profit accruing to each center. Since the general charge is continuous, it is evident that each center must do more than enough work to meet this charge, otherwise it will show a loss; also it is evident that the more work there is done in each center, the greater the profit.

By determining the costs outlined in Table I and classifying them as in Table II, improvements in operating conditions will suggest themselves and if put into effect, the operating costs can usually be reduced. The data in Table II was obtained by the aid of graphic recording meters in connection with motor-driven machine tools. The data in this table is typical of conditions in many large machine

shops. The figures given indicate the following division of total operating charges:

Variable charges.....................from 50 to 55 percent
Salaries ....from 25 to 30 percent
Interest on cost of machine tools......from 5 to 10 percent
Depreciation on cost of machine tools. from 5 to 10 percent
Fixed charges.......................................3 percent
Power ....1 percent

Table II shows no machine-hour rates less than 48 cents an hour. Usually the machine-hour rates are at least 50 percent greater than the operator's pay. It is perfectly evident from this that considera-

TABLE II.—MACHINE HOUR RATES—EXPRESSED IN DOLLARS

TYPE OF MACHINE	CHARGES PER HOUR IN DOLLARS						
	Fixed	Variable	Salaries	Interest	*Depreci- ation	Power	Total, or Mach-Hr. Rate
VERTICAL BORING MILLS—							
40"- 60"	0.02	0.25	0.15	0.05	0.05	0.01	0.53
72"-100"	0.04	0.45	0.25	0.08	0.08	0.01	0.91
10' - 14'	0.05	0.80	0.40	0.15	0.15	0.02	1.57
16' - 24' Ext.	0.08	2.00	1.00	0.30	0.30	0.03	3.71
Av. Percent of Total.	3	52	28	8	8	.1	100
RADIAL DRILLS— 5' . . .	0.02	0.30	0.20	0.03	0.03	0.01	0.59
" " 10' . . .	0.04	0.60	0.35	0.09	0.09	0.01	0.18
Av. Percent of Total.	3	51	31	7	7	1	100
ENGINE LATHES—30"-40".	0.02	0.25	0.12	0.04	0.04	0.01	0.48
" " 40"-60".	0.03	0.50	0.25	0.10	0.10	0.01	0.99
Av. Percent of Total.	3	51	25	10	10	1	100
PLANERS—36"-56"	0.04	0.55	0.30	0.05	0.05	0.01	1.00
" 7' -10'	0.06	1.10	0.60	0.15	0.15	0.02	2.08
" 12' -14'	0.15	2.60	1.40	0.25	0.25	0.03	4.68
Av. Percent of Total.	3	55	30	5.5	5.5	1	100

*It is assumed that machines have been installed six years, so that the depreciation is six percent on basis of ten percent reducing balance. See Fig 1.

tion of the operator's pay alone gives results far from correct, when the total cost of operation is under consideration.

In some cases it has been found that the introduction of individual motor drive has resulted in an increase of 20 percent in production as well as making it possible to obtain accurate data by means of graphic recording wattmeters. To obtain such results, however, the motors must be properly applied and the method of control must be suitable for the service. Machine tool builders are generally prepared to equip old line-shaft driven tools with additional parts to fit them for motor drive; with few exceptions the advantages of motor drive for such machines, if in good condition, are nearly as great as for new machines. Heavier cuts are possible

with motors than with line shaft drive, but the old tools are not usually strong enough to permit taking full advantage of this possibility.

The saving to be made by installing an individual motor may be illustrated by assuming that the 60-in. boring mill cited in Table II was shaft driven. The machine-hour rate is $0.53, and if the workman receives $0.35 per hour, the total operating cost is $0.88 per hour, or $2 470 per year of 2 808 hours (54 hours per week). This machine if properly equipped for motor drive will give at least 20 percent increased output with practically no increased operating cost. Assuming that the machine's earnings are only enough to cover operating expenses, the increased earnings by motor operation will be 0.20×$2 470, or $494 per year.

If both interest at six percent and depreciation at ten percent be considered, $494 represents a capitalization of $3 087; that is, to effect an increase of 20 percent in production, this amount could be added to the investment without change of net profit. This mill can be operated by a 7.5 horse-power motor, and the cost of such a motor, including a controller and the necessary changes in the machine, would amount to possibly $500 or about one-sixth the warranted investment. From the other point of view, the interest and depreciation on $500 at 16 percent is $80, which deducted from the total saving, $494, effected by the motor drive, leaves $414 per year net gain.

In some cases the conditions will warrant the installation of a complete new equipment instead of equipping the old tool with a motor. The new tool will require increased investment, but will make possible more rapid work by taking heavier cuts, thereby warranting the investment. Whether to equip an old machine with a motor or to install a new motor-driven tool is a question calling for careful consideration in order to obtain the best results, as improved methods of applying motors to machine tool operation are continually being developed, and should be taken advantage of when any such changes in equipment are being made.

CONTRIBUTORS TO THE JOURNAL FOR 1909

For more extended notices regarding those indicated by a (*) reference is made to the December issues of previous years.

F. C. ALBRECHT was the first to receive a diploma of graduation from the apprenticeship course of the Electric Company (1899). After being connected with the testing department, took up sales work and for the past one and one-half years, has been in charge of the Mining Dept., Pittsburg district office, Electric Company.

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THE JOURNAL QUESTION BOX

332—POWER REQUIRED BY WATT-METERS—What capacity of potential transformer is required for the voltage coil of a standard single-phase indicating wattmeter; also integrating single-phase wattmeter?   v. s.

A good standard line of indicating wattmeters requires eight watts and a similar line of integrating watt-meters takes ten watts in the pressure coil. The various standard forms of instruments on the market will probably be found not to vary greatly from these values.   H. W. B.

333—TESTING INDUCTION METERS—What objections are there, if any, to testing large capacity, self-contained induction meters as follows: To test a two-wire 100-volt, 100-ampere meter, connected as in Fig. 333 (a), with 500 watts shown on the indicating wattmeter, and
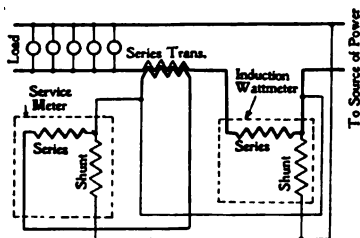
FIG. 333 (a)

the series transformer connected for a ratio of 20 to 1, would it be right to assume that there are 10,000 watts on the circuit through the secondary of the series transformer and series coil of the service meter; in other words, is the ratio of transformation as accurate when used reversed as when used in the way in which it was intended to be used? If there is an error, what allowance should be made? The transformer under considera-

tion is a portable series, plug type, with a ratio of 100-50-25 amperes to five amperes. I tested some meters in this manner and the results were not very satisfactory.   G. D. G.

The ratio of a series transformer will not be correct when used reversed due to the fact that the ratio is not $\frac{Cpr}{Csec} = \frac{Tsec,}{Tpr}$, but nearly $\frac{Cpr}{Csec + W} = \frac{Tsec}{Tpr}$. ($W =$ watts loss in $\overline{E}$ transformer, $E =$ drop across the transformer), *i. e.*, the secondary has less turns than theoretically required. If the transformer is calibrated with a load corresponding to the series coil of the meter, *i. e.*, with the transformer reversed, then the method shown in Fig. 333 (a) will be nearly correct. Otherwise, the error will not be less than 10 to 15 percent. H. F.

334—COMPOSITION OF GRID RESISTANCES—Are the so-called iron resistance grids made of ordinary iron from machine castings or is this metal alloyed with anything else. What is the usual ratio of resistance of these grids to that of copper when the grids are cold? G. K. M.

Resistance grids for use in railway diverters, etc., are sometimes made simply of cast iron, in which case the ratio of their resistance referred to that of copper is 48:1. The effect of alloys is to increase the specific resistance, different firms using different alloys. A definite mixture is usually specified which will serve to materially increase the resistance, give a minimum brittleness, toughness and cost for materials. In this connection, see article on "Elasticity of Cast Iron" appearing in the *American Machinist* for Feb. 4, 1909, p. 194, and article on "Alloys" in the *Gen. Elec. Rev.* for September, 1909.   F. D. H.

335—DIFFICULTY IN STARTING DI-RECT-CURRENT GENERATOR— Please explain why a direct-current generator sometimes refuses to build up when the residual magnetism has by some means been partially destroyed. I have noticed that some generators will build up no matter how low the residual magnetism may be, while in others a comparatively slight reduction prevents their building up. If the armature of a dormant machine is repeatedly short-circuited it will sometimes build up. Please explain this.   C. A. B.

This may be due to dirt under the brushes forming an insulation between them and the commutator. Cases have been known where a generator would not only fail to build up readily but would drop its load for no apparent reason while running normally under load, the whole trouble proving upon investigation to be due to dirt collecting under the brushes. The generator referred to as sometimes building up when repeatedly short-circuited is probably a compound-wound machine, in which case the short-circuiting forms or completes a circuit of very low resistance in which an appreciable current will flow under an e.m.f. of a very small fraction of a volt. The current in the series winding will, of course, be in the direction to aid the shunt field. Or, if the short-circuiting is done at such a point that the series coils are not in circuit, the opening of the slight short-circuit current will give a slight kick to the field which at times may be sufficient to make the generator start to build up.   F. A. R.

336—IRREGULAR BLACKENING OF COMMUTATOR DUE TO STAGGERING OF BRUSHES— As a result of operation under service conditions, one of the direct-current motors of our power system has developed a peculiar condition of blackening of the commutator. Of that portion of the commutator which comes in contact with either the positive or negative brushes, there is a strip which is in contact with only the positive brushes which is highly polished; another strip in contact with both the positive and negative brushes which shows a tendency toward blackening and which is apparently kept polished by the positive and a portion in contact with only the negative brushes which shows pronounced blackening. What is the explanation of the difference in the appearance of these strips under the various sections of the brushes?   R. L. K.

Although the correct way to stagger brushes on a direct-current machine is to have those of opposite polarity trail each other, it is not always done. The commutator is positive to the negative brush, i. e., the current flows from the commutator bar to negative brush. In the case at hand, in that strip of commutator which is blackest, the line current flows in only the direction from commutator bar to brush, because the negative brush only is in contact with it. The dark color is caused by an electrolytic action which is always present when direct current flows between moving contacts from copper to carbon. Copper is an electrolytically active material while carbon is not; hence, when direct current flows from carbon to copper (with moving contact) no such action occurs. The few partially successful attempts that have been made to analyze the resulting thin black deposit show that it is a mixture of oxides of the copper and other metals composing the commutator bars and carbon dust which has the effect of greatly increasing the contact resistance. The trouble can be avoided by correctly staggering the brushes, i. e., so that adjacent brush arms will have brushes exactly trailing. This same effect makes itself apparent on the negative collector rings of large alternating-current rotating field generators, on the positive rings of large homopolar generators, and on the negative rings of homopolar motors, and is much more pronounced when copper brushes are used. That part of the commutator having the medium degree of polish is in normal condition, while the part upon which the positive brush alone trails may be found to be taking very little of the

line current. This blackening of the commutator must not be confounded with blackened bars, which may be found located symmetrically or unsymmetrically around the periphery of the commutator. The latter trouble may be due either to incorrect or insecure connection of the cross-connections to the commutator bars, flat spots, high or low bars, loose bearings, defective pulley or belt, poor design in regard to choice of number of slots, variation in number of turns between bars, poor design of brushes, irregular spacing of brushes, incorrect shifting of brushes, etc. L. A. M.

337—INDUCTION MOTOR EFFICIENCY—Given the horsepower, voltage, amperes, and phase from the name plate of an induction motor, can the efficiency be determined? That is, will it be necessary to know the power-factor and is there any assumption that can be made in general that will be fairly accurate? W. O. M.

To obtain the efficiency from the name plate data, it is necessary to know the power-factor, since, for a single-phase motor the efficiency =

$$\frac{hp \times 746}{volts \times amps. \times P\text{-}F.},$$ where the efficiency and power-factor are expressed in hundredths. For a two-phase motor, divide the second member of the above equation by 2, and for a three-phase motor divide by √3, where *volts* = line voltage, and *amperes* = the amperes per terminal. An assumed power-factor is rather indefinite as this may vary from 94 percent to 65 percent or lower, depending on the size, characteristics and the application for which the motor was designed. If a wattmeter is at hand the power-factor can readily be determined by loading up to the required amperes per phase and measuring real input. Then, of course, P-F = $\frac{real\ input}{apparent\ input}$. M. W. B.

338—THREE-PHASE — FOUR-WIRE TRANSPOSITION — How should the wires of a three-phase—four-wire, 4000 volt transmission line be transposed to neutralize mutual induction? J. D. S.

The transposition of any transmission line involves simply an arrangement of the wires so that the exposure of one wire to the other three is equal throughout the length of the line. In the case of a three-phase—four-wire line, with the four conductors arranged symmetrically to a single cross arm, e. g., this can be accomplished by means of three transpositions made at points which divide the line into four equal sections. Numbering the wires in the first section 1, 2, 3 and 4 respectively, they should have the relative positions of 2, 3, 4 and 1 in the second; 3, 4, 1 and 2 in the third, and 4, 1, 2 and 3 in the fourth section. P. M. L.

339—133-CYCLE FAN MOTOR ON LOWER FREQUENCY—Could a 133-cycle, 110-volt fan motor be re-connected to run on 60 cycles? There are 12 projecting poles on the stator and it has a squirrel-cage rotor and a starting winding. Why will not this motor run as it is on 25 or 60 cycles at reduced speed? S. H. C.

A 133-cycle fan motor such as the above will run on 25 or 60-cycle current, but, due to the reduction in frequency, and hence in inductance, the current taken would be excessive and would result in almost immediately burning out the winding. The speed would drop to 230 r.p.m. on 25-cycle and to 570 r.p.m. on 60-cycle current. At either speed the air displacement would of course be exceedingly small as the blade is designed for operation at 1300 r.p.m. A bi-polar motor on 25 cycles and a four-pole motor on 60 cycles are to be recommended. The only practicable way of operating the above fan motor on 60 cycles would be to reduce the voltage to approximately 55 volts. Although changing the primary connections to adapt the motor to the lower frequency without reducing the voltage impressed might be possible, the rated output would be reduced by one-half and the secondary or rotor copper loss would be doubled. Moreover, the reduction in speed would result in further increase in temperature, due to the decrease in cooling effect. A corresponding change in the starting winding would also be necessary. It is therefore apparent

that it would not be possible to adapt this motor to 25-cycle operation. T. K.

340—CHANGING THE FREQUENCY OF FAN MOTORS—Is it possible to change the winding of 133-cycle fan motors to adapt them for use on 60-cycle circuits; if so, would you be able to send me diagrams illustrating the winding of coils? W. Y. E.

If the motors are of the type designed several years ago, in which the stator was made with distinct poles (alternately positive and negative) having a single coil per pole, and in which the required starting torque is obtained by employing the "shaded" pole principle, then nothing can be done to change the motor for 60 cycles. If it is of modern design, where the number of teeth in the field is some multiple of the number of poles, the required starting torque being obtained by the use of the split-phase principle, the 133-cycle winding can be replaced by four-pole winding, thus adapting the motor for use on 60-cycle circuits. The details of the winding required depends on the form of the field punching, the size of the fan and the voltage for which the motor is to be adapted; hence, in case rewinding is necessary, the most advisable procedure is to send the fan to the manufacturers. T. K.

341—STARTING WINDING FOR INDUCTION MOTOR—A small single-phase induction motor with four projecting poles on both stator and rotor and constructed of laminated iron is wound as follows: stator, 2½ lbs. No. 22, double-cotton-covered wire, each limb of the rotor 200 turns, No. 24, double-cotton covered wire. This motor is not self-starting. I wish to design a starting winding and want the necessary formulae for the same. I understand that the apparent resistance is composed of inductance and ohmic resistance, the combination of which is called impedance. It is this inductance that I do not know how to calculate. How is the size and number of turns of the rotor determined? Please give general formulae as I wish to build a larger

motor of the same type. I do not care about efficiency or losses in this machine. S. H. C.

The simplest way that we can suggest of obtaining self-starting operation for this motor is to provide each primary pole piece with a damper made preferably from "half-hard" or hard sheet brass (to give somewhat higher resistance than would be obtained by the use of copper dampers) fitted into a slot cut to convenient dimensions in the surface of the respective pole pieces and running parallel with the rotor shaft, and of such shape that about one-third of each pole piece will be circumscribed by a damper. These dampers should be arranged uniformly on the respective pole pieces. If thick brass is used, a single thickness may be sufficient for each damper, otherwise they may be built of laminations, if more convenient. The effect of the dampers is to give a lag of the magnetic flux in one-half of each pole piece, thereby causing a split-phase rotating field effect which will produce the necessary starting torque. If the effective air-gap of the motor is very small, the size and number of turns on the rotor may readily be calculated on the assumption that the primary and secondary ampere-turns are approximately equal, as in a transformer. The rotor winding, however, adapts itself to the requirements. If the turns are few, the total length of wire is small and a wire of large cross-section may be used. At the same time the induced voltage in the winding is low and considerable current will be required. If, however, the number of turns is comparatively large, the total length of wire is increased and the size reduced. This is offset by the fact that the induced voltage is increased and the current capacity required thereby decreased in the same proportion. This is on the assumption that the rotor mentioned is the secondary of the motor, and that the stationary part is the primary, *i. e.*, the element connected to the line. M. W. B.

342—BATTERY FOR GAS LIGHTING SYSTEM—A residence electric gas lighting system has developed a leak which can be distinguished with a telephone receiver, but is not, however,

perceptible to the taste, and which runs down the carbon-zinc salamoniac battery within ten or 12 days after it is being charged. It is impracticable to take up the floor or cut the walls in order to repair the circuits. Please suggest, therefore, a form of battery which can be operated under these conditions with re-charging at intervals of two or three months, and still retain sufficient strength to operate a gas lighting system.   W. T. L.

The Edison-Lalande cell will hold up well on closed circuit operation, but the smallest size (100 amp.-hrs.) costs $1.50, and $ .75 for renewal, and three are required to give the same voltage as two salamoniac cells. If the prolific source of trouble in such systems—viz., short-circuits between the metal work of the fixtures and the small fixture wire leading from the concealed wiring to the gas lighters—has been carefully investigated at each outlet and the trouble still exists, we would suggest an inexpensive alternative for the above in the form of a small bell switch by means of which the batteries may be cut out of circuit except when the lighting system is needed.   H. M. S.

343—ENGINEERING TEXT-BOOKS — I am very desirous of obtaining a book or books on steam engines, steam turbines, pumps, and gas engines. I want something that is practical; not too much theory or technicality.
      W. H. A.

The following books will be found to contain valuable information on the above subjects:

A Handbook on Engineering, 1907—H. C. Tulley. The practical care and management of dynamos, motors, boilers, engines, pumps, inspirators and injectors, refrigerating machinery, hydraulic elevators, electric elevators, air compressors, etc.; 906 pages. Price, $3.50.

Mechanical Engineers' Reference Book, 1907—H. H. Suplee. A handbook for all engineers and mechanics. Price, $5.00.

Gas, Gasoline and Oil Vapor Engines, 1907—G. D. Hiscox. Theory, power, design, construction and operation. A book for

gas engine owners, gas engineers and intending purchasers. Price, $2.50.

Gas and Oil Engines, 1890—Dugald Clerk. Including history and practical working. Price, $4.00.

The Steam Turbine—J. A. Moyer. Both theory and practical side. Principles, details of construction, steam consumption, comparison with engines, etc. Price, $4.00.

Gas Power, 1908—F. E. Junge. Complete manual of gas power generation, transmission, application. Chapters on producer gas, gas producers and utilization of low-grade fuels, etc., design and construction of each type with principles involved therein, discussion of standard types and applications.

A reference to various articles on the above subjects, which have appeared in the JOURNAL, will be found on pages 3, 4 and 5 of the Five-Year Topical Index.

344—INSULATION—Where can I find practical information in condensed form, regarding insulation in general such as would be of use to the practical man in the selection of insulating material for the repair of electrical apparatus, and in the selection of high or low voltage insulated wire. What tests can be made to determine the quality of friction tape, applicable to cases where it is used in large quantities?   J. N.

Comprehensive works treating this subject in a general way are rare. We would suggest that considerable information might be obtained from hand-books and other printed matter obtainable from the various manufacturers of the material, which would be apt to be of practical use in applying a given material under its most advantageous service conditions, e. g., hand-books such as are published by the Roebling Co., and the Standard Underground Cable Co., contain valuable information, a great deal of which it would be difficult to obtain from any other source. See also "The Insulating of Electric Machinery," 1907—H. Turner and H. M. Hobart. Price, $4.50. As friction tape is ordinarily made from

such a large variety of materials, more or less indeterminate in quality, and is used in so many different ways, it is difficult to specify any definite conditions of practical use. Good judgment as to the quality of a given lot of material would probably best be used. We believe that many helpful suggestions may be found in the following articles which have appeared in the JOURNAL: "Insulation Testing," C. E. Skinner, September, 1905, p. 538; "Insulation," O. B. More, June, 1905, p. 333; "Taping," C. E. Stevens; "Physical Characteristics of Dielectrics," A. P. M. Fleming, July, 1907, p. 364.

C. E. S.

345—ELECTROLYTIC LIGHTING ARRESTER—What is an aluminum cell lightning arrester and how is it constructed? Would thank you very much also if you would mention the maker and where I can get either catalogues or periodicals on the same   E. J. M^cC.

A description of this apparatus appears in the JOURNAL for August, 1907, p. 469, and further information is to be found in an article on "The Protection of Electric Circuits and Other Apparatus from Lightning and Similar Disturbances" by Mr. R. P. Jackson, in the JOURNAL for March, 1908. In this connection it should be noted that the spark gap curve, Fig. 13, shown on page 163 of this article, has an obvious error in that the values for "Kilo-Volts Across Gap" should be expressed as 10-20-30, etc., instead of 1-2-3. You can probably secure circulars on this subject by addressing a manufacturer of such apparatus.

346—TRANSMISSION LINE CALCULATION—I wish to obtain a copy of the JOURNAL for April, '07, in which I understand there is an explanation of the Mershon Diagram. On p. 232 a three-phase example is given, in which the resistance volts drop is found to be 1 625, and the total volts drop 1 771 volts. To determine the three-phase loss of power in kw, is it correct to multiply the value of current (62.5 amperes) of an equivalent single-phase circuit carrying one-half the kw of the three-phase line, by resist-

ance drop (1 625 volts), and this product by 2, thus: 1 625 $\times 62.5 \times 2 = 20.3$ kw?   E. S. B.

This method is correct. The article in the April, 1907, issue which has been sent you gives a shorter method of calculation than that outlined in Mr. Mershon's article in the JOURNAL for March, 1907, and is further explained in a supplementary article in the same issue.

347—BRUSH LUBRICATION—What is the best lubricant for use in connection with the graphite brushes on the direct-current end of rotary converters in railway service, operating under uniformly heavy load? We have tried substituting sperm oil for the ordinary graphite-paraffine compound for commutator lubrication on our 300, 500, and 1 000 kw, 25-cycle, rotary converters. Trouble has arisen, however, because of pitting of brushes and picking-up of copper on the direct-current end.   M. H. L.

We would anticipate that the trouble experienced has been due to some other cause than the kind of lubrication used for the commutator; probably in the kind of brushes being used. With other conditions as they should be, graphite brushes would require no lubrication beyond the occasional cleaning of the commutator with a rag saturated with paraffine oil. It is possible that in these particular converters the voltage at the surface of the brush during commutation is too great for a low resistance graphite brush and that a higher resistance carbon brush would give better results. This would be almost certain to be the case with 600-volt direct-current converters. If the pitting of the brushes mentioned occurs in the centre of the brush, it is an indication that this is the trouble. We would suggest looking to the brushes rather than to the commutator lubrication for the source of the trouble.

F. D. N.

348—UNDER-CUTTING COMMUTATOR MICA—Many firms cut down the mica between the commutator bars of their motors. Is this safe, and how deep is it permissible to slot it? Can the groove be filled with some compound so as to give quiet

running? Would the use of wax or any commutator lubricant be safe when this is done? c. v. e.

The slotting of commutators has become an almost universal practice on large railway systems in the United States, although it may not be done in your vicinity in England. It has been found that the commutator life is very greatly increased, and especially with the use of a softer brush, partly graphitic in character. Burned commutators, flat spots and flashing are greatly reduced providing proper brush tension and proper brushes are employed. No oil or compound should be used with these commutators, either for lubrication of commutator or for filling of slots. Very little difficulty is experienced with short-circuiting between bars if the slot is about 0.040" wide and not over 0.06" deep. Note also No. 32, March, 1908. j. l. d.

349—DETERMINING THE WINDING OF DIRECT-CURRENT RAILWAY MOTOR—The old winding of the armature of a 50 hp type of motor was taken out and destroyed before the throw of the coils in the slots or the lead of the commutator connections was determined. Is it possible to calculate this information with the following data: 45 armature slots, 135 commutator segments, four poles, and brushes set midway between the poles j. e. w.

Throw of Coil—In a four-pole motor the throw of the coil is approximately one-fourth of the circumference of the armature. In the usual design, although the motor will run with a coil throw of one-fourth of the circumference of the armature, the best operation is secured by making the throw somewhat less. Thus in the case cited, one-fourth of $45 = 11\frac{1}{4}$, and the best operation is probably secured with the coil in slots No. 1 and No. 11. It is impossible to give an exact rule for this, but this is about the usual reduction.

Throw of Leads on Commutator—The throw of the leads on the commutator is either one-half bar more or less than half way around. The first gives a progressive winding and the second a retrogressive winding. Changing from one to the other of

these will reverse the direction of rotation of the armature, but will not otherwise affect the operation of the motor. In the case cited, $\frac{1}{2}$ of $135 = 67\frac{1}{2}$. Then the throw of the leads for a progressive winding is from bar No. 1 to bar No.69, and for retrogressive winding it is from bar No. 1 to bar No. 68.

Connection of Coil to Commutator—The particular bars to which any coil should be connected is determined by the relative positions of the poles and the brush holders. The fundamental principle to be remembered is that the coil whose two sides lie between the tips of adjacent poles should have its leads conected to the bars which are at that time passing under the brushes. Usually the brush holder is placed opposite the center of the pole, and in this case the leads are spread out equal distances from the center of the coil. To determine the proper layout in this case, place one coil on the core in its proper slots. Take the center of the slot or tooth which is half way between the two sides of the coil, and by means of a straight-edge find the corresponding point on the commutator. Count each way from this point half the number of bars included by the throw of the leads as already determined, and mark these bars. This should check by counting from one marked bar to the other. When there are two or more leads per coil, the marked bars should be used for the middle leads in the case of an odd number of leads, or for one of the two middle leads in the case of an even number of leads. If the brush holders are placed midway between the poles, as is stated in the example, it will be seen that in order to have a coil commutate when it lies between the pole tips, the leads from one side of the coil must come straight out, and connect to the bars which are opposite the slot in which that side of the coil lies. The leads from the other side of the coil must be brought around so as to give the proper spacing of leads on the commutator. e. l. w.

350—VOLTAGES IN INCANDESCENT LAMP CIRCUIT—With two 110-volt, 16 c-p incandescent lamps connected across a 220-volt circuit and the connections between the two lamps so ar-

ranged that the circuit can be opened at this point and a volt-meter inserted, it appears that the reading of the volt-meter when so connected is the same as the line voltage. If the voltage across these two adjacent terminals of the two lamps is thus 220 volts, what would be the voltage across each lamp? Knowing that each lamp can take only one-half ampere and that when connected in series across the line, this is the maximum current flowing, it would seem that the drop across each lamp would be 110 volts; this is not consistent with the voltmeter reading as above noted. Please explain.   J. E. W.

When burning in series, the current on the two 16 c-p lamps would be one-half ampere as noted, and the drop across each lamp would be one-half of the total voltage or 110 volts. The apparent discrepancy observed with the voltmeter inserted between the lamps is accounted for by the fact that the ohmic resistance of the ordinary commercial voltmeter is so great as compared with the resistance of the lamps that the drop in voltage across the lamps is negligible compared with the voltage drop across the voltmeter terminals, and hence the voltmeter indicates the same as the line voltage. This is based on the well-known principle that the e.m.f. drop across resistances connected in series is proportional to the values of the respective resistances.

351—METHOD OF DE-SULPHATING STORAGE BATTERY PLATES — What is the best method for reducing sulphation of storage battery plates?   S. F. McD.

The electrolyte should be removed and replaced with water in which the plates should be soaked for two or three hours. If the specific gravity of the resulting electrolyte is below approximately 1.060, add a sufficient quantity of electrolyte to raise it to this value. If the specific gravity is too high, add water. Charge at normal rate, and continue the charge at normal rate, after the density and voltage have ceased to rise, for eight hours. Finally, replace with electrolyte of proper specific gravity. Note

also "The Care and Maintenance of Storage Batteries" by Mr. F. A. Warfield, in the JOURNAL for August, 1908, p. 466.   L. H. F.

352—COMPOUND MOTORS IN PARAL-LEL—Two 75-hp, 250-volt, di-rect-current, compound-wound motors are geared to a con-veyor line shaft, both motors being controlled by a single starting box. Motor *1* meshes directly with the gear wheel on the conveyor shaft, while an idler is inserted between motor *2* and the driven gear. Please suggest a scheme of connection such that the mo-tors will share the load equally.   E. B. W.

If the two motors are of the same type, size, speed and design, they should share the load equally with-out difficulty, providing the shunt and series fields are respectively of the same strength in the two ma-chines. If they are of different de-sign, it will be necessary to adjust one of the shunt fields for equal strength by means of an external field resistance, and then to adjust the two series fields for equal com-pounding. The latter could be ac-complished by means of series field shunts to be used in parallel with that series field of the motor which does not take its share of the load after adjustment of the fields. Ad-justment of the shunt field should be made to assure of equal field excita-tion in the two machines. This may be done by operating the motor on no load with the series fields of the two machines temporarily eliminated. A wattmeter or ammeter in the arm-ature circuit of each machine would serve to indicate when the load was equally divided with shunt field ex-citation alone. With this condition satisfied, it is now only necessary to have equal compounding in the two series fields to assure equal distribu-tion of load throughout the full range of the machines.   F. A. R.

353—POWER-FACTOR CORRECTION — Two 2 400-volt, three-phase, generators having a total out-put of 600 hp are located re-spectively one mile and two miles from their load. The total load of 150 hp is shared by a second high-tension

power system operating in parallel with the above through the medium of a sub-station. The power-factor at this point is only 50 or 60 percent. How large a synchronous motor would be required to raise the power-factor at the point of consumption to about 90 or 100 percent, and how much power would be required to drive this motor?

                                                                        H. L. H.

The low power-factor involved may be found to be due to the large circulating currents between the two systems; there is, however, insufficient data to draw a reasonable conclusion regarding this point. Assuming, however, a simple case of power-factor correction, handled by the method described by Mr. Wm. Nesbit, in the article on "Synchronous Motors for Improving Power-Factor" in the JOURNAL for August, 1907, p. 425, a graphic solution similar to that shown in Fig. 353 (a) will be obtained, in which AE represents the total kw capacity $= 850$ hp, and
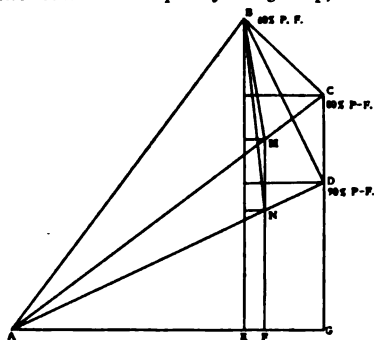
FIG. 353 (a)

$AB =$ the corresponding capacity in k.v.a. at 60 percent power-factor. Then the k.v.a. capacity of a synchronous motor of sufficient size to raise the power-factor to 90 percent, the motor carrying no mechanical load except that required to supply its losses, is represented by $BN = 530$ k.v.a. BD represents the capacity of synchronous motor required to give same results with the motor carrying 200 kw mechanical load (including losses equal to ten percent). Size of motor running light required to raise power-factor to 80 percent =

330 k.v.a. represented by BM, while $BC = 300$ k.v.a. $=$ capacity of synchronous motor required to raise power-factor to 80 percent when the motor carries 200 kw total mechanical load.   E. S. Z.

354—DETERMINATION OF POLARITY BY MEANS OF COMPASS—In testing a four-pole exciter for polarity, it is found that, when a compass is held outside the yoke at the point where the field pole is bolted to it, a south pole is indicated. If the machine is now started and the voltage allowed to build up to about one-third of normal value, the compass needle slowly reverses direction, apparently indicating that the polarity of the field at this point has been reversed. Why is this?   C. O. R.

In the ordinary permanent bar magnet, the extended lines of force are shown in the familiar form il-

(a)

(b)
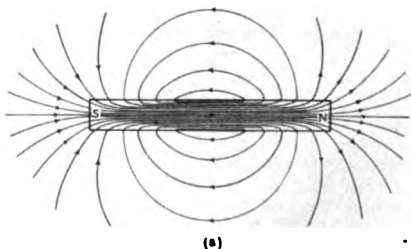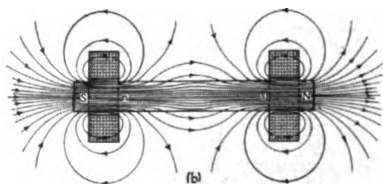
FIGS. 354 (a) and (b)

lustrated in Fig. 354 (a). The maximum induction in the iron is at the middle of the magnet. If, now, two coils be placed near the ends of the magnet and current is passed through them in such a direction as to increase the strength without destroying the direction of the ordinary magnetic lines of force, local lines of force will be produced in the medium surrounding the coils as shown in Fig. 354 (b) and there will be a weak resultant

field behind each coil as indicated at *n* and *s*. This tendency to circulate around the coils will obviously be increased with increase of current if the cross-section of the magnet between the coils be small or if its permeability be low. It is obvious that in the generator or motor the pole faces correspond to the free ends of the bar magnet and that, accordingly, the leakage magnetic lines emenating from the space around the yoke between the field coils into the surrounding medium will reverse in direction when the current is applied, in the same way that they reverse in the medium surrounding the middle of the bar magnet, between the coils.   C. F. S.

355—MARBLEIZING SLATE SWITCH-
    BOARDS—Please give informa-
    tion regarding process for
    marbleizing slate switchboards.
                                    E. F. B.

The slate is cut, trimmed, beveled, and sand-rubbed in the usual way. If a particularly smooth finish is desired, it should be honed. Then apply one coat of black ground paint; dead black is ordinarily used for this, but any good flat color paint will do. Allow this coat to dry thoroughly before applying next coat. A tank of water several inches wider than the largest piece of slate to be marbleized should then be provided. On the surface of the water float the various colors to be used in mottling, and, with a finger or stick, draw them out to resemble the markings of marble. Then immerse the slate in the clear water and bring it up under the colors that have been spread out on the surface. If this is carefully done, the colors will stick to the slate, forming the same design on the slate that has been drawn on the surface of the water. Allow these colors to dry and apply suitable varnishes for finishing. J. R. S.

CONTRIBUTORS TO THE JOURNAL QUESTION BOX 1909

Much of the popularity and value of the Question Box is due to the large number of experienced men who have aided in furnishing replies to enquiries. Many of these men are extremely busy and engaged almost constantly along special lines of work. Each answer has been prepared or approved by an acknowledged expert on the subject in question. This fact, while well known to many of our readers, will be made more evident from the following list of those who have assisted in furnishing replies. Where not otherwise indicated the names given are those of men connected with the Westinghouse Electric and Mfg. Company.

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H. E. BRUMELLE, in charge of Standard House.

G. W. CANNEY, superintendent of erection.

L. W. CHUBB, research division, engineering department.

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E. E. LEHR, industrial division, engineering department.

P. M. LINCOLN, general engineer, engineering department.

J. J. LINEBAUGH, engineering department, General Electric Company, Schenectady, N. Y.

T. D. LYNCH, research division, engineering department.

R. A. McCARTY, industrial division, engineering department.

C. P. McGIBBEN, power division, engineering department.

H. G. MacDONALD, detail and supply division, engineering department.

PAUL MacGAHAN, detail and supply division, engineering department.

L. A. MAGRAW, detail and supply division, engineering department.

J. E. MATEER, industrial division, engineering department.

H. C. NAGLE, detail and supply division, engineering department.

F. D. NEWBURY, power division, engineering department.

E. PATTERSON, chemist, Universal Portland Cement Co., Universal, Pa.

RALPH W. POPE, secretary, American Institute of Electrical Engineers, New York City.

K. C. RANDALL, engineer in charge, transformer division, engineering department.

E. G. REED, transformer division, engineering department.

CLARENCE RENSHAW, railway division, engineering department.

F. A. REW, industrial division, engineering department.

A. B. REYNDERS, general engineer on insulation, engineering department.

J. R. SANBORN, research division, engineering department.

C. H. SANDERSON, detail and supply division, engineering department.

H. M. SCHEIBE, detail and supply division, engineering department.

CHAS. F. SCOTT, consulting engineer.

C. E. SKINNER, research division, engineering department.

R. A. SMART, assistant manager of works.

H. C. SPECHT, industrial division, engineering department.

E. C. STONE, transformer division, engineering department.

P. H. THOMAS, of Thomas & Neall, consulting engineers, Boston and New York.

E. L. WILDER, railway division, engineering department.

T. WHITEHEAD, industrial division, engineering department.

F. E. WYNNE, railway division, engineering department.

E. S. ZUCK, Cleveland district sales office.

PERSONALS

Mr. S. L. Nicholson has recently been appointed general sales manager of the Westinghouse Electric & Mfg. Co., and has direct charge over the sales policies of the entire company. Mr. Nicholson has been with the company for 11 years in many different capacities as salesman, as district department sales manager, and as industrial and power sales manager for the past five years. Before coming to the Westinghouse Company he was with the C. & C. Electric Company. He is perhaps best known to motor manufacturers as the organizer and president of the American Association of Motor Manufacturers, an organization which has done much in the two short years of its life to improve the art of manufacturing motors.

Mr. Charles Robbins, who has for many years been connected with the Westinghouse Electric & Mfg. Co. in the industrial and power sales department in connection with the sales of industrial motors, has recently been appointed manager of this department. Mr. Robbins has been with the company since 1899, in which time he has been in the manufacturing department, the New York district office sales department and for the past three years in the industrial and power sales department at East Pittsburg. His headquarters will continue to be at East Pittsburg.

Mr. Arthur J. Sweet, the well known illuminating engineer, has left the Westinghouse Lamp Company to accept an important position in the engineering department of The Holophane Company at Newark, Ohio. In his new position he will have charge of certain new development work which the Holophane Company has been planning for some time.

Mr. H. R. Stuart has resigned his position with the Radio Telephone Company, of New York, to enter the sales and engineering department of the H. S. Sands Electric & Mfg. Company, of Wheeling, W. Va.

Mr. C. E. Allen, formerly of the General Electric Company, is now with the Westingnouse Electric & Mfg. Company in the transformer sales department.

BOUND VOLUME NOTICE

After January 1st, 1910, the price of bound volumes of THE ELECTRIC JOURNAL for the years 1904 and 1905 will be $5.00 each, prepaid.

Some very interesting lectures have been delivered recently at The Electric Club (Pittsburg), among them being those by Mr. W. S. Murray, electrical engineer of the N. Y., N. H. and H. R. R., on "Results of Operation of Single-Phase Locomotives in Trunk Line Service"; by Mr. J. M. Barr, manager of the industrial motor department of the Electric Company, on "Shop Opportunities for the Technical Graduate"; by Mr. H. A. Hornor, electrical engineer of the New York Ship Building Company, on "Electrical Marine Engineering," and by Prof. John Price Jackson, dean of the Engineering School of Pennsylvania State College, on "The Versatile Manager."

TRADE NOTES

According to the verdict of experts, the Rail Joint Company's products have the most perfect distribution of metal to insure the most satisfactory results. The base supported rail joints are of three types—the Continuous joint, the Weber joint and the Wolhaupter joint. The Continuous joint consists of two angle bars with an extra broad bearing on the tie, with the lower flanges bent inward to form the base plate. The Weber joint is made up of four parts—an ordinary angle bar, a channel fitting into the rail into which is fitted a wood filler. This serves to act as a cushion when the bolts are clamped against the outer metal support of special shape. The Wolhaupter joint consists of angle bars, the lower flanges of which are bent in to grip a corrugated base plate.

The Central Electric Company, Chicago, Ill., is distributing a bulletin entitled "Economical Meter Testing with the P-M Meter Testing Block," which should prove of considerable service to superintendents of central station meter departments. This circular shows the various methods of testing all types of meters now on the market by means of a large number of diagrams.

THE ELECTRIC JOURNAL is published by The Electric Club. THE JOURNAL is unique in having the support of an active electrical society which numbers among its members the engineers of a large electric company, as the club is composed principally of men connected with the Westinghouse Electric & Manufacturing Company.

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NEW BOOKS

"Welding and Cutting Metals by Aid of Gases or Electricity"—L. A. Groth. Nine illustrations, 281 pages. Published by D. Van Nostrand Company, New York City. Price, $3.00.

This book is the most elaborate work in English that has as yet appeared on a subject which is to-day receiving the closest study from manufacturers of mechanical apparatus. The author has undoubtedly devoted a great deal of time to the study of welding in its various forms and has gathered together a large amount of useful information which has heretofore existed in fragmentary shape. The subject is, however, such a broad one that it is an exceedingly difficult matter for any single individual to cover properly all of its ramifications and for this reason it would, perhaps, have been better had the book been rather more confined in its scope. The author's lack of familiarity, too, with the English language, has in some instances resulted in his not being able to express himself clearly to the average reader. A further criticism may be legitimately made in the lengthy quotations from previously published articles. Despite these features, there is a great deal to be gained by a careful perusal of the book. The early chapters are devoted to general remarks on welding and contain as well some interesting facts and data on allied subjects, including the manufacture of oxygen, hydrogen, water-gas, acetylene, etc. These are followed by descriptions of the leading systems of welding, oxyhydrogen, oxy-gas, oxy-acetylene, alumino-thermic, water-gas, arc and incandescent with a chapter devoted to blowpipes of various kinds. C. B. A.

"Direct and Alternating Current Testing"—Frederick Bedell; 256 pages, 115 illustrations. Published by D. Van Nostrand Company, New York City. Price, $2.00.

This manual is prepared primarily for students. The experiments are presented in the form of laboratory instructions, although the author has in many cases included discussions of principles and theory.

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  Bridgeport Brass Co., New York, N. Y.

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  Cutter Electrical & Mfg. Co., Philadelphia,
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American Hard Rubber Co., New York.

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